A Survey of 2015 Mid-South Irrigation Practices:

Report to the Mid-South Soybean Board

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Contents

1 Introduction 17
1.1 Project Parameters 17
1.2 Developing Acreage Datasets 18
1.2.1 Adjust Participants' Data ? 20
1.3 Irrigation Data Developed 20
1.3.1 Data Facts 22
2 Irrigation Survey 24
2.1 Survey Participant Pool 25
2.2 Participants Interviewed for Survey 26
3 Types of Questions 30
3.1 Participatory Questions 30
3.2 All That Apply/Best Choice Questions 32
3.3 Data Input Questions 32
3.4 Participatory Plus Questions 33
3.5 All-inclusive Question Series 33
3.6 Regarding Number of Questions in Survey 35
4 Irrigation Data Collected 36
4.1 General Irrigation Questions 36
4.2 Areas of Focus for the *USBIP* Investigation 37
4.2.1 Irrigation Best Management Practices (*IBMP*s) 37
4.2.2 Adoption History 42
4.3 Tallying Mid-South Irrigated Acreage 45
4.3.1 Multi Methods Afforded for Totalizing Survey Acreage 46
4.3.2 SUMS or PAIRED VALUES for Tallying 47
4.4 Separate Crop Domains 48
4.4.1 Crop-Specific Results 50
5 Irrigated Acreage in the Study 51
5.1 Acreage count based on TYPES of CROPS ($Acres_{CP}$) 54
5.2 Acreage count based on IRRIGATION METHODS ($Acres_{IM}$) 54
5.3 Acreage count based on LAND SURFACE ($Acres_{SF}$) 58
5.4 Acreage count based on PUMPs ($Acres_{P}$) 61
6 Importance of Survey Data 62
7 Analyzing Data 64
7.1 Validity of Study 66
7.1.1 Sample Size Validity 66

7.1.2 Initial Observations Regarding Data ... 66
7.1.3 Data Validity ... 67
8 Background of Individuals ... 73
8.1 Residency ... 73
8.2 Land Ownership ... 73
8.3 Years of Farming Experience ... 76
8.4 Educational Background ... 78
8.5 Household Income ... 79
8.6 Size of Farm ... 80
8.7 Participation in Farm Programs ... 83
8.8 Yield Levels of Survey Participants ... 85
8.9 Surface Shaping ... 88
8.9.1 An Influencing Factor on Surface Shaping: ... 91
9 Water Resources ... 92
9.1 Concerns regarding Water Sustainability ... 92
9.2 Source of Irrigation Water ... 96
9.3 Irrigated Area per Pump ... 100
9.3.1 Further Insight Regarding Pump Number ... 101
10 Factors Influencing Practice Adoption by Irrigators ... 103
10.1 Funding Sources ... 104
10.2 Reasons for Adopting ... 106
10.2.1 Tailwater recovery / storage reservoirs ... 107
10.2.2 Precision Leveling ... 111
10.2.3 Computerized hole selection ... 114
10.2.4 Surge irrigation ... 117
10.2.5 Multiple Inlet Rice Irrigation ... 120
10.2.6 Summary of reasons for IBMP adoption ... 123
11 Energy ... 124
11.1 Pumps and Energy Sources ... 124
11.1.1 Sources of Energy Used in Pumping ... 125
11.2 Projected Energy Savings ... 126
11.3 Timers ... 127
11.4 Water Meters ... 129
11.4.1 An Influencing Factor on Water Meters: ... 131
12 Conservation Practices ... 134
12.1 Storage Reservoirs ... 134
13 Methods of Farming ... 137

13.1 Crop Mix ... 137
13.2 Cover Crops ... 141
13.3 Single Crop Husbandry ... 142
13.4 Rice ... 145
13.4.1 Special Irrigation Methods used in Rice Cultivation ... 147
13.4.2 Applying Rice Water ... 152
13.4.3 Irrigation Scheduling for Rice ... 152
13.4.4 Rice Acreage ... 153
13.4.1 Irrigated Row Crop / Rice Acreage ... 157
13.5 Soybean ... 157
13.5.1 Non-soybean Growers. ... 157
14 Methods of Irrigation ... 159
14.1 Types of Irrigation Systems ... 166
14.1.1 Pressurized Systems (e.g., center pivots) ... 166
14.1.2 Gravity Irrigation Systems ... 168
15 Irrigation Best Management Practices (*IBMP*s) ... 173
15.1 Associated Energy Savings from *IBMP*s ... 173
15.2 Accumulated Adoption Curves ... 177
15.3 Storage Reservoirs ... 182
15.4 Tail Water Recovery ... 183
15.5 Computerized Hole Selection ... 184
15.6 Surge Flow ... 186
15.7 Precision Leveling ... 187
15.8 Zero Grade ... 189
15.9 Multi-Inlet on Rice (MIRI) ... 191
15.10 Irrigation Scheduling ... 193
16 Conclusions ... 200
17 References ... 202
18 Appendices ... 204
18.1 Appendix I – Data Validity ... 204
18.2 Appendix II – Estimating Value of Datapoint with “I don’t know” in the Dataset ... 206
18.3 Appendix II – Dealing with Possible Errors in the Dataset ... 208
18.4 Appendix III - Categories of Questions – Types of Information Garnished ... 209
18.5 Appendix IV -- Consistency in Survey Results ... 209
18.6 Another Appendix ... 210
18.7 Acreage count based on CORRECTED DATA ... 210
18.7.1 Deriving Acreage Based on Hybridizing Separate Data ... 210
18.7.2 Deriving Acreage Based on Reducing Outliers ... 210

18.7.1 Deriving Acreage Based Modifying Suspected Data 211
18.8 (5th) Overall RICE-Specific Acreage based on RICE CULTURAL PRACTICES 211

List of Tables

Table **Page**

Table 1. The number of responses to questions *Q41* and *Q42* on surge flow irrigation and x, ∑, and % of furrow irrigation using surge. 21
Table 2. *Telephone Call Log* 24
Table 3. Completion rate for participants that began the telephone survey 26
Table 4. The number of irrigator participants, their acreage, and their % of national totals. [A] 27
Table 5. Total final survey participants by state who provided data and percent of original contacts 29
Table 6. The number of questions responded to by participants 30
Table 7. Type of questions asked in the survey. 30
Table 8. Types of IBMPs categorized into groups, plus information on whether start time & acreage amount (B) was collected 38
Table 9. Questions by categories in the irrigation survey. 39
Table 10. Part of the Information collected regarding various Irrigation Best Management Practices (Col. A); it includes Date Practice was Adopted (Col. C) and the Expected Energy Savings (Col. J). The question number is indicated. 40
Table 11. Irrigated Acres Summation Methods showing Acres, n and Ratio Value 45
Table 12. Summation Methods for Irrigated Acres 47
Table 13. Domains by crops grown. 48
Table 14. The number of available methods by which to calculate respondents' irrigated acreage 51
Table 15. Factors of crop-related acreage ($Acres_{CG}$) compared to irrigation-related acreage ($Acres_{IM}$) and land surface-related acreage ($Acres_{SF}$) 55
Table 16. Ranking of irrigation methods by total area and number 57
Table 17. Number of pumps per farm and irrigated acres served per pump 61
Table 18. % of participants who provided either a YES or a NO response. 65
Table 19. Sample size, R^2 and % of original n for demarcation blocks with and without outliers 68
Table 20. The p-values for mean acreages of rice versus field crops with and without outliers 69
Table 21. Statistical information between ALL and OUTLIER-REMOVED acreages using crop- versus irrigation-method summations of farm irrigated acres for rice, all field crops but rice, and all crops. 69
Table 22. The survey states, their counties & number of participants 73
Table 23. Size of samples and % for type of ownership stake 74
Table 24. Irrigated and dryland acreage in the region as reported by USDA 75
Table 25. Student t-test results for mean values of owners (x) and renter (y), $\alpha = 0.05$ level 75
Table 26. Student t-test results for mean values of owners (x) and renter (y), $\alpha = 0.20$ level 76
Table 27. Years of farming experience for owners & renters by state, sample size shown as (n) 77
Table 28. Scale used to quantify educational level 78
Table 29. Mean educational level scores by state based on values from Table 28 78
Table 30. Percentage of participants with agriculture degrees 78
Table 31. Household income scale 79
Table 32. Mean household income level by state based on values from Table 31 79
Table 33. Estimated mean household income by state based on values from Table 31 & Table 32 79
Table 34. The % of land controlled by the top 10 and 20% largest landowners by crop and state 83
Table 35. Participant-provided yield estimates 86

Table 36. Comparison of anticipated crop yields (w/ & w/out outliers) to USDA/NASS totals 87
Table 37. Land surface treatments by type of irrigation (S.E. Mo. & N.E. Ark., 1998) 88
Table 38. Land surface finishing by state. 89
Table 39. Farmers' depth-to-water change (Q13) in their irrigation wells & their percent of sample 93
Table 40. Perceived groundwater shortage severity by irrigators for their own farm and for their state.. 94
Table 41. The average number of water sources (Q11) participants used for irrigation 97
Table 42. Component portions of water source contribution based on two separate calculation procedures for the mid-South irrigation water. 98
Table 43. Average number of pumps, irrigated land area, and acres / pump per respondent................ 101
Table 44. Farmers providing data on the number of their pumps. 102
Table 45. Adoption parameters and questions regarding various *IBMP*s 103
Table 46. Total gravity irrigated farms determined using four summation methods 104
Table 47. Funding sources for four *IBMP*s 105
Table 48. Percentage funding of TWR systems & number of sources... 105
Table 49. Type of funding source.. 105
Table 50. Funding sources for Tail Water (TWR) Recovery Implementation.. 107
Table 51. Main reasons given for adopting on-farm storage of water 107
Table 52. Other reasons cited for adopting the practice of on-farm storage.. 109
Table 53. Main reasons given for adopting precision leveling 111
Table 54. Other reasons cited for adopting the precision leveling.. 112
Table 56. Reasons provided for adopting or not adopting CHS... 116
Table 58. Reasons provided for adopting or not adopting surge irrigation 119
Table 60. Reasons provided for adopting or not adopting MIRI 122
Table 62. Estimated energy savings from nine IBMPs in the mid-South, showing mean and number. Also shown are higher-end potentials (maximum & 90%- and 80%-percentiles) and percent of sample reporting ZERO energy reduction. 126
Table 63. Percentage of farmers who USE / DO NOT USE pivots 127
Table 64 Percentage of farmers having at least one electric pump & those have none. 128
Table 65. Percentage of irrigators with either in-place or portable water meters by state..................... 129
Table 66. Average 2015 yields between irrigators with a water meter and those not having one for four crops. 130
Table 67. Percentage of irrigators with any type of flowmeter by state; MS data is broken down as being within YMD boundaries or not 131
Table 68. In AR, LA, MS, and MO, the Number and Total Farm Acreage for All Farms with Tailwater Systems (TWSs), plus Same Data for Farms NOT Growing Rice that have TWSs; the relative Percentage of Rice-Growing Farms to All Farms is also shown... 135
Table 69. Area serviced with Storage Reservoirs (avg., s.d., sum, min & max), SRs per farm, and avg. farm size & portion of it serviced with SRs 135
Table 70. Total Acreage, maximum and minimum values in the sample, mean size and its standard deviation and number by crop and state. 139
Table 71. Total Acreage, maximum & minimum values in the sample, mean size and its standard deviation, sample size, and percentile farm size values from 0.1 to 1.0 at 0.1 increments by crop for the mid-South region. 140
Table 72. Participant responses regarding use of cover crops 141

Table 73. AR, LA, MS, and MO Irrigators from Survey Who Grew Rice in 2015: Sample Size and % of Sample by State, % of Irrigators Who Grew Rice, Average Reported Rice Acreage, and Total Sample Area (Acreage and % of USDA/NASS amounts) ... 143
Table 74. AR, LA, MS, and MO number of irrigators from survey who in 2015 (a) grew no rice, (b) rice along with one or more other crops, (c) monoculturally, and (d) % of monocultural farms. ... 143
Table 75. Number of irrigators in AR, LA, MS, and MO from survey who in 2015 for the crops corn, cotton, soybeans, and rice (a) grew no rice, (b) rice along with one or more other crops, (c) monoculturally, and (d) % of monocultural farms ... 144
Table 76. Number of different irrigation methods employed by individual irrigators ... 149
Table 77. Reported acreage of irrigation methods used on rice (and its %) by state ... 149
Table 78. Rice yield, standard deviation, sample size and USBIS to NASS yield ration by state ... 151
Table 79. The four methods that rice acreage could be determined ... 153
Table 80. 2015 planted acreage of all crops and for rice and their ratio ... 156
Table 81. Ratio of reported 2015 acres to that of management practices, irrigation methods and land leveling; sample size: (n) ... 156
Table 82. The years of irrigation experience (and s.d.) for those who did/didn't grow soybeans ... 158
Table 83. How acreage data was collected and analyzed ... 159
Table 84. Acreage Data (number, sum and mean) by state as collected in the survey ... 160
Table 85. Acreage Data (number, sum and mean) by state arranged by traditional method groups ... 161
Table 86. Differences by state in gravity and pressurized irrigation: number of users and area. ... 162
Table 87. Center pivot acreage, number and % (by area and user) and information about pivot owners' gravity irrigated acreage ... 166
Table 88. Ratio of fixed pivots to towable pivots ... 166
Table 89. Proportion of farmers indicating having used fixed and towable pivots and exhibiting 2015 acreage in the same ... 167
Table 90. Percentage of sample who had indicated YES regarding towable pivots & had 2015 fixed pivot acreage ... 168
Table 91. Gravity Irrigation Systems & border component ... 169
Table 92. The three gravity irrigation methods used on field crops & portion that is border irrigation 170
Table 93. Border irrigation of row crops based on users ... 171
Table 94. In field crops the proportion of border fields to all gravity irrigated fields ... 171
Table 95. Anticipated energy savings from nine irrigation practices ... 174
Table 96. Expected energy savings from various IBMPs –total number of responses (zeroes, non-zeroes, & rebuffs) and average energy savings (both as reported and with zero responses removed) ... 175
Table 97. Earliest Year of Adoption of Precision Leveling, Average Year of Adoption, and number in AR, LA, MS, and MO ... 179
Table 98. The use of surge flow – total regional acreage, amount per farm, and % using ... 186
Table 99. Irrigation scheduling methods used by the participants ... 193
Table 100. The anticipated yields & sample size for irrigators using, or not using, soil moisture sensors 193
Table 101. The anticipated yields & sample size for irrigators using, or not using, computer scheduling 194
Table 102. The anticipated yields & sample size for irrigators using, or not using, Woodruff graphs ... 194
Table 103. The anticipated yields & sample size for irrigators using, or not using, routine scheduling ... 196
Table 104. The anticipated yields & sample size for irrigators using, or not using, probe or feel ... 196
Table 105. The anticipated yields & sample size for irrigators using, or not using, watching neighbors .. 197
Table 106. Yield differences between Sensor Users and non-Sensor Users in the mid-South ... 197

Table 107. Some of the survey data values associated with two different participants who exhibited outlier status. 204
Table 108. Some of the survey data values associated with two different participants who exhibited outlier status. 206
Table 109. Reported 2015 rice acreage value compared to rice acreage amount derived from reported irrigation method used, land surface amounts, and watering method amounts. 212
Table 110. Methods to tabulate acres of rice 212

List of Figures

Figure **Page**

Figure 1. Farm irrigated acreage as determined using two methods, showing 1-to-1 line and absolute discrepancy above and below this line. 20

Figure 2. The % of all furrow acres employing surge flow vs Years of farming experience.......... 22

Figure 3. Pie chart showing candidate pool for irrigators to be interviewed. [C] Refused telephone interview; [D] Owner only, didn't irrigate; [E] Retired, health, deceased; [F] Disconnected number; [G] 2nd party refused or communication problems; [H] No answer, busy or couldn't be reached before end of surveying period 25

Figure 4. The number of survey participants by county 28

Figure 5. The % of contacted irrigators who refused to participle in the study by state 29

Figure 6. Timelines of participants' adoption of four different *IBMP*s common to the Mid-South. 43

Figure 7. Crop domains percentages by participants and total acres. 49

Figure 8. *USBIS* data on 2015 crop acres versus calculated acres based on (top) irrigation systems, (mid) land surfaces, and (bottom) number of irrigation pumps. 52

Figure 9. The histogram showing the frequency of occurrences of variance percentages. 53

Figure 10. In the *USBIS* irrigated acreage was calculated by summing the components of the three broad categories of gravity, pressurized, and rice irrigation. 57

Figure 11. The area (top) and the number of users (bottom) for all major irrigation methods. 58

Figure 12. Crop acres compared to irrigation method (top) and surface (bottom) acres. 60

Figure 13. Owner's Irrigated Acres versus the Number of Irrigation Pumps 61

Figure 14. Map showing g 62

Figure 15. The three broad categories of irrigation in the USBIP report (gravity, pressurizes and rice-related) shown in pie chart with their sub-components illustrated in the bar chart. 66

Figure 16. Farm irrigated acreage as determined using two methods, showing 1-to-1 line and absolute discrepancy above and below this line. 68

Figure 17. Comparing acreage amounts derived using $Acres_{IM}$ versus $Acres_{CG}$ using all values: (top) Rice, (mid) all non-Rice crops, and (bottom) all rice & non-Rice crops 70

Figure 18. Comparing acreage amounts derived using $Acres_{IM}$ versus $Acres_{CG}$ with outliers removed: (top) Rice, (mid) all non-Rice crops, and (bottom) all rice & non-Rice crops 71

Figure 19. State-by-state comparison of acreage amounts calculated by crop- versus irrigation method-tallies with outliers removed. 72

Figure 20. Histogram showing participants' years of farming experience 77

Figure 21. Irrigated acres per respondent based on ownership (owning or renting) by state. Also shown are USDA (2012) values for average irrigated farm acreage calculated by two methods: Total farm irrigated area (Table 2) and Σ of all major irrigated crops (Table 24) 81

Figure 22. Relationship of years of farming experience and size of farm 81

Figure 23. The % of the irrigated corn land controlled by landowners based on their corn farm size in mid-South (illustrating that 10% of the largest corn land holders controlled 40% of irrigated corn acres) 82

Figure 24. Frequency histogram, number of conservation programs participating 85

Figure 25. Map, acres of multi-slope per county and location of Opti-Surface regional headquarters 91

Figure 26. Map, average perceptions of irrigators of groundwater shortage in their state with 1 being "no problem" and 5 being a "severe problem" 94

Figure 27. The perceived groundwater shortage index for “your farm” & “your state” vs. number of water sources used 95
Figure 28. State average irrigation water resources on rice farms. Gwr = ground water; Str (D) = stream (direct); Str (S) = stream (stored); Str (S) + TWR = stream (stored) + Tail Water; Rsvr/Twr (n.o.s.) = Reservoir or Tail Water (no outside source); WD = Water District 97
Figure 29. Source of irrigation water for mid-South vs. national average 98
Figure 30. Histogram of irrigated acres per pump 101
Figure 31. Pie graphs showing main reasons for adopting on-farm water storage for the 4-state region and states individually. 110
Figure 32. Primary Reasons Farmers adopt CHS 114
Figure 33. Primary Reasons Farmers do not adopt CHS 115
Figure 34. Other Reasons Farmers do not Adopt CHS 115
Figure 35. Reasons for adopting surge flow irrigation 118
Figure 36. Reasons for not adopting surge irrigation 118
Figure 37. Reasons for adopting MIRI 121
Figure 38. Reasons for not adopting MIRI 121
Figure 39. Number of participants’ pumps derived from two separate sources 125
Figure 40. Timer use relative to % of farm irrigated by pivots. 127
Figure 41. Timer use relative to % of pumping units that are electric. 128
Figure 42. The relative yields for metering and not metering based on the average reported crop yield.130
Figure 43. The region of the Yazoo Mississippi Delta Joint Water Management District (YMD) shown within mid-South map. The density of irrigation wells in the YMD shown in the inset map of Mississippi & a YMD datasheet on their *Voluntary Metering Program*. 131
Figure 44 Percentage of water meter use in counties. 132
Figure 45. Percent of irrigation farms having some amount of storage reservoirs 134
Figure 46. Average size of acreage of various irrigated crops when present. On farm Cutout above bars is the % of farms the crop was found in 137
Figure 47. Pie charts illustrating portions in acres for six irrigated crops in the mid-South. Bottom: average size over all 466 farms in the survey. Top: average size based on only farms having that crop 138
Figure 48. Cover crops grown by mid-South irrigators 142
Figure 49. The number of farmers that grew no rice, rice along with one or more other crops, or rice monoculturally by state 145
Figure 50. Histograms of state rice yields showing outliers assumed to be caused by a misunderstanding on units of yield 147
Figure 51. Irrigation methods used to water rice, mid-South 150
Figure 52. Methods used to irrigate rice, by state 150
Figure 53. Individuals’ reported irrigated acreage based on 2015 planting values to sum of rice watering management strategies. 154
Figure 54. Comparing rice irrigation methods from *USBIP* and USDA/NASS 157
Figure 55. Portions of users who have all pivot, all gravity, or a combination of pivot and gravity 163
Figure 56. Main broad grouping of irrigation methods (pivot & flood [i.e., all gravity methods) and all forms on rice). Rice methods broken down in pie chart – all 4 states 164
Figure 57. Main broad grouping of irrigation methods (pivot & flood) and all forms on rice). Rice methods broken down in pie chart – by state (clockwise, starting at Top Left: AR, LA, MO, and MS 165
Figure 58. % of respondents who indicated YES but listed no 2015 acres for 6 irrigation methods. 167

Figure 59. Relative value of respondent's values of Q28a to the sum of Q28b + Q28c 169
Figure 60. Average of nine *IBMP* histogram responses 175
Figure 61. Histograms of expected energy savings for farmers for nine *IBMP*s, showing trends to be skewered to the left. Zero-grade (bottom, right image) was the least skewed response 176
Figure 62. Adoption rate history of three *IBMP*s in the mid-South during different periods: early (TWR), mid (CHS), and late (SMS) 180
Figure 63. Adoption rate history of storage reservoir use in the mid-South... 182
Figure 64. Adoption rate history of tail water recovery use by state in the mid-South 183
Figure 65. Numbers of farmers employing tail water recovery use in the mid-South 183
Figure 66. Adoption rate history of tail water recovery use in the mid-South.. 184
Figure 67. Adoption rate history of computerized hole selection by state in the mid-South 184
Figure 68. Adoption rate history of computerized hole selection in the mid-South 185
Figure 69. Adoption rate history of surge flow in the mid-South 186
Figure 70. Adoption rate history of precision leveling by state in the mid-South 188
Figure 71. Adoption rate history of precision leveling in the mid-South.. 188
Figure 72. Adoption rate history of Zero-grade in the mid-South 189
Figure 73. MIRI use in precision grade and contour levee rice.. 191
Figure 74. Adoption rate history of soil moisture sensing in the mid-South 198
Figure 75. Crop- vs Irrigation Systems-summation methods plotted together as full view [A] and blowup view of same [B],. Blowup has outlier datapoints (caused because Irrigation System = 0) circled. Crop- vs Land Surface-summation methods using the circled outlier datapoints with R^2 = 0.86 is seen in [C]. Thus, those values could be substituted in for missing data points... 207

Text Box **Page**

Text Box 1. Survey question series Q143 re: participant's expected yields 12
Text Box 2. Survey question Q2 re: land ownership and whether operates the farm 15
Text Box 3. Survey question Q136 re: years of farming experience... 18
Text Box 4. Survey question series Q47 : a secondary means to estimate irrigation acreage 22
Text Box 5. Survey question series Q103 : a means to compare estimated irrigated acreage 22
Text Box 6. Survey question series Q97: a means to compare estimated irrigated acreage 23
Text Box 7. An example Q3 series question: do you produces this crop using irrigation......................... 26
Text Box 8. Question Q53 can serve as an indicator validifying responses on other questions 28
Text Box 9. Survey question Q13 re: participant's opinion on water level changes 31
Text Box 10. Survey question series Q14 re: participant's opinion on groundwater shortage 31
Text Box 11. Survey question Q15 re: participant ranking groundwater shortage problem 32
Text Box 12. Survey question series Q11 re: participant's sources of irrigation water............................. 35
Text Box 13. Survey question series Q97 re: participant's method of irrigating rice 43
Text Box 14. Survey question series Q97 re: participant's acreage using MIRI... 46
Text Box 15. Survey questions Q100-102 re: MIRI – when, why, & why not 47
Text Box 16. Survey questions Q49-52 re: precision leveling – when, why, funding, & why not.............. 48
Text Box 17. Survey question Q98 re: precision leveling – when & funding 49
Text Box 18. Survey questions Q97_6c re: Amount of zero-grade land is continuous rice....................... 49
Text Box 19. Survey questions series Q103 re: Rice acreage based on water application strategy........... 50
Text Box 20. Survey questions series Q104 re: Rice irrigation scheduling methods 51
Text Box 20. Survey questions series Q95-96 re: Use & type of cover crops 53

Overview

In the mid-South:

- Survey results came from 466 different mid-South irrigators.
- Soybeans are the most ubiquitously grown irrigated crop.
- The number of irrigated acres belonging to those surveyed was not homogeneous.
- Five out of every six farms (83%) employs at least one electric pump.
- Producers cited economic reasons in almost 50% of the cases of ***IBMPs*** adoption.
  - Graphical adoption rate timelines on these practices often show when irrigators' interest keenly increased.
- The survey was thorough (≈10% of USDA/NASS on corn, cotton, rice and soybean acreage contacted).
- Regarding the query YES/NO, I grow this crop under irrigation, all responded, with 0% prevaricating[1].
  - Re: its acreage, 61%, and then re: the yield of that crop, 39% supplied prevaricating responses.
- The participation rate of a farmer using various practices (e.g., planting of a particular crop, use of irrigation scheduling, practice surge flow, etc.) appeared to be a more reliable statistic than the acres involved.
  - Thus, increase/decrease of the percentage of farmer participation over time is a more reliable metric to measure adoption than is reported acreage differences in time.

<u>When referencing the mid-south survey data or this report use the following reference:</u>

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This report can be found at http://www.uaex.edu/irrigation

The datasets from this report can be requested from,

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[1] Prevaricating responses include: REFUSED, or I DON'T KNOW, or just not answering.

Definitions

NOTE: The variables immediately below are acreage values. They represent the irrigated acreage in the study for the crops being irrigated by the participants with "crops" being segmented in three ways: ALL CROPS (***$Acres_{XX}$***), RICE ONLY (***R_Acres_{XX}***) and NON-RICE CROPS (***FC_Acres_{XX}***). The variable used as subscripts are: Crops Grown ($_{CG}$), Irrigation Methods ($_{IM}$), Soil Surface Condition ($_{SF}$), Hybridized Value ($_{HYB}$), and Rice Watering Methods ($_{RWM}$).

ALL CROPS

$Acres_{CG}$	∑ of irrigated acres, all participants for main crops[2] reported on 2015 planted acreage (Q137_1 … Q137_6) (acres).
$Acres_{IM}$	∑ of irrigated acres, all participants based on reported irrigation methods being used (Q28b, Q28c, Q30, Q32, Q62, Q63, Q97_1 … Q97_5) (acres).
$Acres_{SF}$	∑ of irrigated acres, all participants based on reported soil surface conditions (Q47_1 … Q47_4) (acres).
$Acres_{P}$	∑ of irrigated acres, all participants based on reported # of pumps on the farm (Q69 or Q76 … Q81) (acres).
$Acres_{HYB}$	∑ of irrigated acres, all participants based on hybridized data set using either *$Acres_{IM}$* or *$Acres_{SF}$* value closest in value to *$Acres_{CG}$* (acres).

RICE ONLY

R_Acres_{CG}	∑ of irrigated rice acres, all participants for only rice reported on 2015 planted acreage (Q137_4) (acres).
R_Acres_{IM}	∑ of irrigated rice acres, all participants based on only reported rice irrigation methods being used (Q97_1 … Q97_5) (acres).
R_Acres_{SF}	∑ of irrigated rice acres, all participants based on reported soil surface conditions (Q47_1 … Q47_4) prorated by the factor of *R_Acres_{CG}* / *$Acres_{CG}$* (acres).
R_Acres_{P}	∑ of irrigated rice acres, all participants based on reported # of pumps on the farm (Q69 or Q76 … Q81) (acres).
R_Acres_{HYB}	∑ of irrigated rice acres, all participants based on hybridized data set using either *R_Acres_{IM}* or *R_Acres_{SF}* value closest in value to *R_Acres_{CG}* (acres).
R_Acres_{RWM}	∑ of irrigated rice acres, all participants based on only reported rice watering methods used (Q103_1 … Q103_3) (acres).

NON-RICE CROPS

FC_Acres_{CG}	∑ of irrigated non-rice acres, all participants non- rice reported on 2015 planted acreage (Q137_1 … Q137_3, Q137_5-Q135_6) (acres).
FC_Acres_{IM}	∑ of irrigated non-rice acres, all participants based on reported non-rice irrigation methods being used (Q28b, Q28c, Q30, Q32, Q62 & Q63) (acres).
FC_Acres_{SF}	∑ of irrigated non-rice acres, all participants based on reported soil surface conditions (Q47_1 … Q47_4) prorated by the factor of *FC_Acres_{CG}* / *$Acres_{CG}$* (acres).
FC_Acres_{P}	∑ of irrigated non-rice acres, all participants based on reported # of pumps on the farm (Q69 or Q76 … Q81) (acres).
FC_Acres_{HYB}	∑ of irrigated non-rice acres, all participants based on hybridized data set using either *FC_Acres_{IM}* or *FC_Acres_{SF}* value closest in value to *FC_Acres_{CG}* (acres).

NOTE: The variables ***GI, PS*** and ***RI*** below are the component parts of ***$Acres_{IM}$***.

GI	∑ of gravity-irrigated non-rice acres (Q28b, Q28c, Q30, Q32) (acres).
PS	∑ of pressurized-irrigated (center pivot and micro-irrigation) non-rice acres (Q62 and Q63) (acres).

[2] Main survey crops were corn, cotton, soybeans, rice, grain sorghum and peanuts.

RI ∑ of all irrigation methods servicing rice acres (Q97_1 … Q97_5) (acres).

NOTE: The variables ***Method I … III*** below are generic terms for acreage summation methods independent of the crops being referenced.

Method I Generic reference to ∑ of irrigated acres for all participants based on reported irrigation methods either being used for all crops ($\boldsymbol{Acres_{IM}}$) or for rice only ($\boldsymbol{R\_Acres_{IM}}$) (acres).

Method II Generic reference to ∑ of acres for all participants based on reported soil surface status either being used for all crops ($\boldsymbol{Acres_{SF}}$) or for rice only ($\boldsymbol{R\_Acres_{SF}}$) (acres).

Method III Generic reference to ∑ of irrigated acres for all participants based on rice watering methods for rice only ($\boldsymbol{R\_Acres_{IM}}$) (acres).

USBIP The United Soybean Board Irrigation Project.

USBIS The United Soybean Board Irrigation Survey that was developed as part of the USBIP.

USBIPR The reported results of the United Soybean Board Irrigation Survey.

$\overline{x}$

1 Introduction

In 2014, four mid-South states (Arkansas, Mississippi, Louisiana, and Missouri) received a grant from the United Soybean Board and the Mid-South Soybean Board designed to increase the profitability of irrigated soybean growers in the mid-South. The project's goal was to increase the adoption of Irrigation Water Management Practices. A survey of irrigators in the region was conducted as a baseline for adoption rates of commonly used practices. Many of the cultural practices used in the mid-south are not documented, due to the uniqueness of this region that is not found in the rest of the United States. This survey is meant to supplement the Farm and Ranch Irrigation Survey conducted by the National Agricultural Statistics Services. Additionally, the survey provides Extension and researchers and other stakeholders with key benchmark information about where to direct educational programs and where state and federal resources would provide the most benefit.

Although data was collected on several beneficial irrigation practices, three irrigation best management practices (***IBMP***s) were of special interest to the study group for several reasons. First, these three practices had been the subject of recent endeavors targeted in Extension educational outreach efforts aimed at local irrigators. Secondly, it had been demonstrated that these ***IBMP***s were beneficial. And, thirdly, the ***IBMP***s were identified as being good candidates for transferability since farmers appeared willing to adopt on their farms. These three ***IBMP***s were:

- Improved irrigation timing specifically soil moisture sensors adoption
- computer hole selection (CHS), that is, assuring proper orifice size in the mainline poly-pipe delivery lines.
- Surge flow irrigation
- Multiple Inlet Rice Irrigation
- maintaining pumping plants at high levels of efficiency.

The project, in large, would be evaluated on the level of grower adoption of these new practices after three years of efforts; hence baseline data was needed to be collected to ascertain project success. Although, the genesis of the project stemmed from soybean-related funds, data concerning other six other major crops was gathered at the same time. And among this group, other irrigation-related information was collected on rice because of the additional practices specific to it alone. The data from this survey represents irrigation practices that occurred in 2015

This project is termed the United Soybean Board Irrigation Project (*USBIP*) and was funded by the United Soybean Board and the Mid-south Soybean Board representing Arkansas, Mississippi, Louisiana, Texas and Missouri.

1.1 Project Parameters

The *USBIP* had three original parameters, which were:

Parameter One. Conduct a four-state[3] survey of current irrigators to establish baseline data, *The United Soybean Board Irrigation Survey* (*USBIS*).

Parameter Two. Develop and conduct educational programs on irrigation efficiency methods. Efforts were to include:

- On-farm result demonstrations of ***IBMP***s.
- Develop and hold quality irrigation conferences.

[3] All of Arkansas, Louisiana, Mississippi, and the "Bootheel" area of southeast Missouri.

- Produce ancillary irrigation educational products, such as, news stories, fact sheets, field day presentations, etc.

Parameter Three. Evaluate impact on improvements in irrigation skill levels of regional farmers by follow-up survey, or by measuring changes being made in irrigated yields as garnished from third party publications.

The first two components making up Parameter Two have been met, and the fruits of which have been shared with growers. This report represents fulfillment of Parameter One. A thorough survey of mid-South irrigators and their practices was completed as part of the *USBIP,* and its findings are being reported on in this publication. These results will then provide the required baseline information to establish pre-study irrigation levels and practices. Future comparisons to these benchmarks will provide a means to evaluate the project to determine if its goals were met, as well as, to quantify its level of impact on clientele. This is the primary reason for the survey, and to this end, PIs and Co-PIs (hereafter just referred to as "PIs"), with the assistance of statisticians, invested much effort in developing the set of questions to ask and the protocols to be used in the survey.

In addition, the PIs were cognizant that in process of collecting irrigation data, (a) the specialists might learn about some fresh, bottom-up, farmer-inspired innovations currently in use by irrigators, but unknown to the PIs, and worth promulgating to others, and (b) motivate leaders to form new interagency alliances in future irrigation educational programs, etc. To this end, some of the questions in the survey purposely gathered insight on irrigators' sources of information, their sources for funding, etc.

1.2 Developing Acreage Datasets

In 2012, approximately 8½ million irrigated acres of the mid-South study's six crops of interest[4] were planted in that region (USDA/NASS, 2014). The *USBIS* was able to capture 12 to 14% of these total acres in its survey efforts.

When researchers first began to dive into the *USBIP* data trove, they were anxious to develop procedures to quantify just how many irrigated acres had been surveyed. The prime method for this compilation task was simply to sum up the acreage for the six irrigated crops (***Acres$_{CG}$***) obtained from the straightforward ***Q137*** series of questions in the survey instrument (which were saved in adjacent columns in the *USBIS* database). This procedure was direct and uncomplicated, plus the data was subject to little likelihood of error stemming from interpretation misconceptions.

Also, of interest to the researchers was what --and their acre quantity-- were the various irrigation methods that were being employed in the mid-South. However, in contrast to the straightforward crop summation effort, this new method (***Acres$_{IM}$***) required that a participant's individual data point value, representing the sum of all the acres that were being watered by all the different methods on his farm, was derived from summing up values from eleven different data columns, some of which were not totally straightforward and were subject to possible misinterpretation. Nonetheless, with two separate summation methods now in hand, the opportunity was thus afforded for researchers to integrity-check the *USBIS* data through cross-referencing the two datasets.

All data being discussed are in units of acres. The total acreage sums (as well as individual paired data points) for both methods should be in close agreement, but inevitably there will likely be small differences between the methods for various reasons. In order to quantify the difference between procedures (and help in appraising data quality) a RATIO procedure was developed. The prime dataset selected in making comparisons between groups was the straightforward ***Acres$_{CG}$*** dataset (in its inverse form). Since the ***Acres$_{CG}$*** sum value was generally

[4] The six crops of interest in the *USBIP* were corn, cotton, soybeans, rice, grain sorghum and peanuts.

smaller than the other summation methods, the RATIO normally turns out to be an integer value, slightly greater than one, as shown below:

$$Ratio = \frac{Acres_{IM}}{Acres_{CG}} = \frac{1{,}206{,}406\ acres}{1{,}024{,}113\ acres} = 1.178$$

A perfect match between any two methods would lead to the Ratio = 1.000. Since the actual *USBIS* data was used for the above example, we can state that the study's Ratio value appears to be fairly good and would be considered as being acceptable plus.

However, earlier, there had been some slight disappointment among researchers on the fit between the crop- and irrigation system-based tallying methods. In a previously published report (involving only the Arkansas participants [43% of *USBIP* respondents]) the estimated Ratio was found to be 1.50, a value that is too high, indicating the likelihood of some error. Northern Economics, Inc (2017) explained things and reported:

> *Total irrigated acres by irrigation method is different from total irrigated acres by crop, because figures come from different survey questions. Respondents may irrigate the same acres using multiple methods, use different methods than those asked about in the survey, or give inconsistent figures.*

In investigating further, however, it turned out that the survey data actually had been good. The Alaska-based, Northern Economics Inc. had a misinterpretation regarding the furrow irrigation queries that had been asked about, resulting in irrigation system acres (***$Acres_{IM}$***) being overestimated. The actual Ratio for this Arkansas group should have been 1.29.

Other Acreage Summation Methods. It turns out, that a third –and later, even a fourth (***$Acres_{P}$***)[5]-- summation method for totalizing study acreage were also available; the former coming from the participants' supplied responses on their farm's acreage for various surface finished conditions on all their irrigated land, gathered from the ***Q47*** series of questions, and herein referred to as ***$Acres_{SF}$***. All four of the above-mentioned summation techniques (***$Acres_{CG}$***, ***$Acres_{IM}$***, ***$Acres_{SF}$***, and ***$Acres_{P}$***) were compiled using the responses from all 466 participants.

Rice Acreages. As will be discussed later, four separate sub-level data summations could also be constructed for the sub-set: farmers-who-grew-RICE, using the same parameters as before. And, since an additional rice-specific question had been posed, a fifth rice-specific summation method also existed. In comparing eight of the different permutations for testing pairs of datasets,[6] it was found that the average Ratio value for the group was 1.085, indicating that, overall in the *USBIS*, there is quality and consistency among totalization methods.

However, despite overall Ratio being close to the desired value of 1.00, we recognize that some error is present. This becomes readily visible when plotting together the crop acreage summation (x-axis) with other of the irrigation method summations (y-axis). Here **Figure 1** plots the ***$Acres_{CG}$*** and the ***$Acres_{IM}$*** together. First, it is seen that the scatter of datapoints do not directly lie on the 1-to-1 line, but slightly above it (indicating the Ratio > 1.0). But also, two data points are visible that are very obvious outliers: in one case it shows an incident where irrigation system acreage as reported by one respondent is underreported by 12,100 acres, while in another case, the participant overreports his irrigation system acreage by 11,400 acres.

[5] ***$Acres_{P}$*** is the database used to quantify the acreage involved in the *USBIS* based on the number of irrigations pumps on the farm.
[6] More will be said regarding the nature of these seven groups of questions in section **3.5 All-inclusive Question Series**.

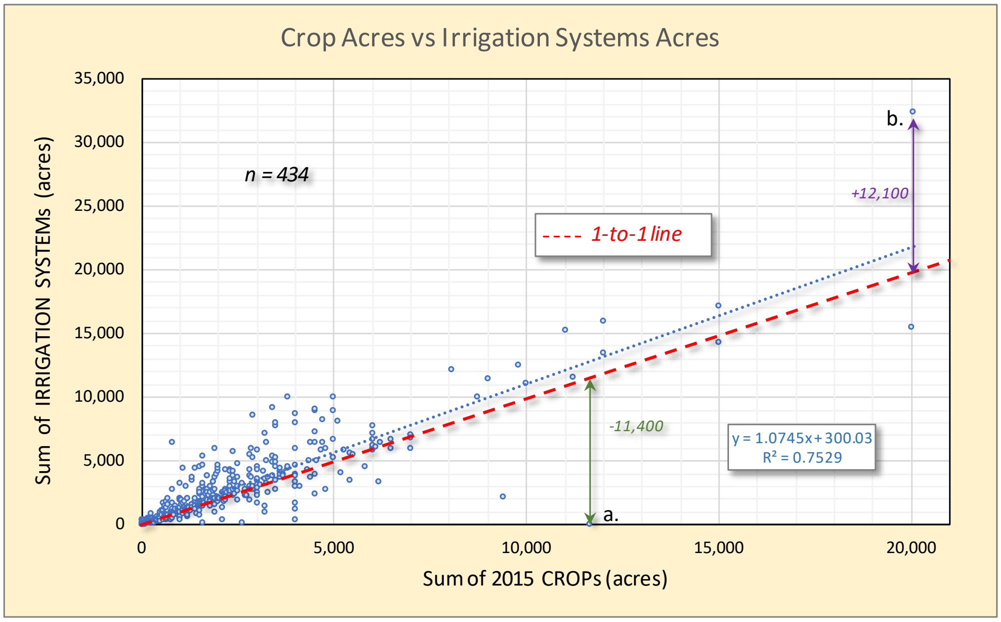


Figure 1. Farm irrigated acreage as determined using two methods, showing 1-to-1 line and absolute discrepancy above and below this line.

1.2.1 Adjust Participants' Data ?

Understanding that an individual's number of irrigated acres as calculated from the several methods, should all be in close agreement with each other, **Figure 1** graphically attested that is not so. A graphical image such as an X-Y graph is able to be produced since there are two datasets being compared with one another. One can quickly pinpoint where data problem areas might exist, such as at points **a** and **b**. However, should even a third dataset also be available an additional benefit is opened up: crosschecking now becomes possible, and a substitute value for an outlier could be contemplated. But, should questionable datapoints be amended?

Although a case can be made to "adjust" participant-supplied survey values, this was not done by the authors, other than in the cases where rice growers were confused regarding the queried for unit of yield.

Appendix I includes information on methods to cross check data.

1.3 Irrigation Data Developed

Irrigation Data Facts. Using an example, the survey showed that 93 respondents said YES regarding having ever used surge flow. Then just a few questions later, only 72 respondents would report on how many acres of surge they had, while another 6 refused to provide the acreage amount. Among those 72 positive responses, one appeared faulty (only 10 reported acres?), leaving just 71 valid responses. Collectively, a little over thirty-one thousand acres were identified as being irrigated with surge flow. **Table 1** shows some of the survey results regarding surge flow.

Concerning whether the farmer had said YES on ever using surge before, 21.4% (after removing the 31 *Don't Know*, etc. replies) responded affirmatively. Eventually, just 71 irrigators provided a valid acreage amount for their farm, with many of the former YES-respondents now either in the *Refused* column or reporting 0 acres – this converts into a user participant rate of 17.2%. Those two percentage values, ≈21% and ≈17% of the users, marked in aquamarine highlight thusly in the table, represent excellent markers reflecting mid-South irrigation as of 2015.

Those two values, 21% and 17%, are *participation rate values* and represent the best metric for comparing change that may have taken place at future survey dates. Thus, in the future, these participation values can be used in comparisons to determine if change has occurred, as well as, in quantifying this amount. On the other hand, the 31,291 recorded surge acres from the 466 *USBIP* participants isn't as good a ruler for marking future changes. **Table 1** also shows another reliable marker that can be used in comparisons to determine if change has occurred, and that is the fact that in 2015 5.7% of all furrow irrigation was using surge flow.

Table 1. The number of responses to questions ***Q41*** and ***Q42*** on surge flow irrigation and $\bar{x}$, ∑, and % of furrow irrigation using surge.

Regarding question ***Q41*** -- YES/NO Have you <u>ever</u> used surge irrigation?				Regarding ***Q42*** -- How many of your total irrigated acres use surge irrigation?				∑ of Surge Flow	$\bar{x}$ of Surge Flow	Percent of surge flow to all furrow irrigation
Question	n	(n)	(%)	Question	n	(n)	(%)	(acres)	(acres/farm)	(%)
No	342	342	78.6%	No	342	342	82.6%			
Yes	93	93	21.4%	YES, # of acres	71	71	17.4%			
Don't Know, Refused, Left blank	~~31~~	~~31~~	---	YES, Refused	6	~~6~~	---	31,291	440.7	5.7%
				YES, w acres = 0	15	~~15~~	---			
				YES, but faulty data	1	~~1~~	---			
Sum	~~466~~	435	435	Sum	435	414	413			

<u>Irrigation Data Correlations</u>. Derived facts from the survey can be used to develop relationships to other groups of facts taken from the survey, as shown in **Figure 2**, the % of a farmer's furrow-irrigated acres that uses surge relative to the years of farming experience for that individual.

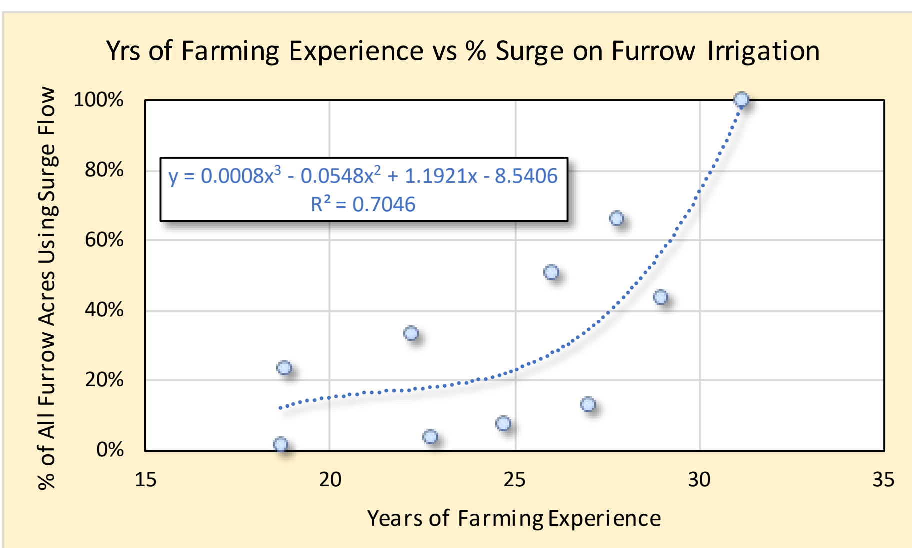


Figure 2. The % of all furrow acres employing surge flow vs Years of farming experience.

Two key points facts about correlating data from the survey are:

- The presentation is done in pairs, with two datapoints being required. All singletons must be removed.
- Outlier datapoints (as seen previously in **Figure 1**) also should be removed.

An option exists for circumventing both of these faulty data problems, and that is to "modify" the recorded response by supplying an appropriate value to pair up with the singleton value in the first case, or to identify the miscreant value in the outlier pair, and change it in the second case.

1.3.1 Data Facts

In an earlier section (***1.2.1 --Adjust Participants' Data ?***), it was discussed that ways do exist to estimate "corrected" values for suspect datapoints, and the possibility of supplanting with them. However, as mentioned, the authors chose not to do so and will merely include data modifying information in the appendices. One reason for this is that the "finetuning" of datapoint pairs is mainly important only in correlations. Also, even if the datapoint quantity provided by an interviewee might seem to be questionable, the fact that he is involved with it is not. Thus, *user participation rate* skirts the error.

A data fact can be either a number value or a percentage value, for example, "93 users" or "17.4% of users". The latter form represents *participation rate.*

The *user participation rate*, an item requiring little second guessing, turns out to be a reliable way to quantify current -- and future-- irrigation activity in the mid-South. When used in conjunction with published government irrigation databases, such as the USDA/NASS's irrigation surveys published every five years, acre estimates, also, can be attributed for the various irrigation practices. The benefits of user participation rates are:

First, developing information regarding the <u>percentage of study irrigators</u> employing a practice is very useful. Growers appeared to be more forthcoming in answering if they used a practice or not, then in providing the exact number of acres they had of that practice. In the majority of cases when acreage information regarding a practice was asked about in the survey, it had been first proceeded with the simple question of YES/NO, do you …?

Secondly, the point in time during the interview process that a question was posed, apparently has bearing. This was significant on the acreage of irrigated crops. The phone interview process lasted from one to two hours. It appears that queries made earlier in the process would be more reliable, as at this point both the participant and the interviewer were fresh, compared to how they might have been later in the process. For instance, the data used to determine the exact number of acres of the various irrigated crops on a participant's farm (i.e., the ***Acres***$_{CG}$ data) was collected in this manner: within minutes of starting the interview, the farmer was asked "*YES/NO Do you produce ____ crop under irrigation?"* for the six crops in quick succession. At the tail end of the interview, maybe two hours later, the topic was again revisited, and the participant was now asked for the number of these acres for each of the six crops. Over 14% of the time, those that earlier had said YES to a crop, did not supply the number of acres of that crop.

Thirdly, these YES/NO questions are participatory type of question (c.f., **3.1 Participatory Questions**) and invoke a quick response. In contrast, the answer of exactly how many acres might require the participant to take the time to mentally, or on a sheet of paper, make the required hand calculations before being able to determine an actual value. Recalling that the average size of irrigation holdings for participants in the *USBIS* was very large, nearly 3,000 acres. So, it is understandable that in the process of answering up to 259 questions in the survey, especially in light of their large number of holdings, some snap estimates may have been made.

Fourthly, many times, farmers used prevaricating responses (e.g., REFUSED, or I DON'T KNOW, or just by not answering) that would keep survey totals lower than they actually were. For example, regarding the acreage of various crops under irrigation, 61% of the response were of this nature, so total acreage was probably under reported (especially for cotton). Again, even sans an acreage value, tallying up a YES fills in the profile of the participant in regards using a practice.

General conclusion:

> *For the reasons above, the <u>participation rate of farmers</u> using various practices (e.g., planting of a particular crop, use of irrigation scheduling, practice surge flow, etc.) is a more reliable statistic than is the summed acres involved. In light of the fact that of one the prime motives for the USBIP was to document changes that will occur, and that the increase/decrease of the percentage of farmer participation over time may be a more reliable metric in measuring adoption than is reported acreage differences, we encourage this metric to be used in future impact studies involving the USBIP.*

2 Irrigation Survey

In 2016 a survey representing the 2015 crop year was undertaken to gather information on current irrigation practices in four mid-South states: Arkansas, Louisiana, Mississippi, and Missouri[7]. The study was, funded with support from the United Soybean Board (USB) and the Mid-South Soybean board and carried out by extension staff in agricultural engineering and agronomy from each of the states' land grant universities. Mississippi State University and the University of Arkansas were the primary universities involved in the *USBIP*. Specifically, the result of the project's survey report is referred to as the *USB Irrigation Survey (USBIS)*.

Describing the step-by-step process in which pertinent, eligible mid-South irrigators were contacted for the *USB Irrigation Survey* report (***USBISR***) is thoroughly described in Edwards, 2016. From a potential application pool of over 8,000 people from the four involved states, the list was ultimately reduced to 466 survey informants. Particulars of the selection process, regarding the numbers involved in the culling step processes, are shown below on this page and are printed in *italic*. These data are taken directly from Edward's report.

Methodology

In collaboration with a team of agricultural research scientists, a survey was designed to better understand the types of irrigation systems used by agricultural producers in a catchment area covering the states of Mississippi, Arkansas, Louisiana, and the bootheel region of Missouri. The contact information for the agricultural producers was obtained from Survey Sampling International. This included all commercial crop growers identified by Dun & Bradstreet records for the given catchment area (n=8,572). A telephone-based survey secured a total of 466 completed interviews.

Data Specifications

- *Each telephone number in the sample was dialed at least 10 times before it was retired (unless a final disposition had been attained prior to the 10th call attempt).*
- *System missing codes in the dataset and Item Response Frequency Tables indicate that a given question did not apply, based on the respondents' answers to previous questions.*

Table 2. *Telephone Call Log*

Final Disposition Code	*MS*	*AR*	*LA*	*MO*	*Number*
Completed survey	*148*	*199*	*93*	*26*	*Number retired*
Respondent refused	*182*	*247*	*138*	*48*	*Number retired*
Refused to continue survey during administration	*206*	*171*	*181*	*23*	*Number retired*
Someone refused (Not the person listed in the sample)	*1*	*8*	*1*	*0*	*Number retired*
Retired from farming or no longer in business	*161*	*250*	*99*	*37*	*Number retired*
Landowner only (not involved in crop growing)	*423*	*375*	*408*	*72*	*Number retired*
Business is not involved in crop growing	*152*	*157*	*113*	*27*	*Number retired*
Health problem, deceased, or otherwise unavailable	*70*	*119*	*49*	*11*	*Number retired*
Communication or language problem	*3*	*11*	*1*	*0*	*Number retired*
Already completed survey under a different contact listing	*1*	*5*	*1*	*0*	*Number retired*
Disconnected number	*102*	*842*	*91*	*20*	*Number retired*
No Answer / Busy Signal / Voicemail	*759*	*1,321*	*961*	*236*	*Returned to queue*
Scheduled callback: As requested by respondent	*8*	*7*	*2*	*6*	*Returned to queue*
Total Telephone Numbers Purchased:	***2,216***	***3,712***	***2,138***	***506***	
Cooperation Rate*:	***27.6%***	***32.3%***	***22.8%***	***26.8%***	$= \frac{Completes}{Completes + Refusals}$

* High lighting used to indicate the disposition codes used in calculating cooperation rate.

[7] For Missouri, only the southeastern portion of the state, enclosing the northern part of delta of the Mississippi River, was surveyed. This region is often referred to as the Bootheel.

The survey captured 1.02 Million irrigated acres of the 13.3 million acres reported in the region by NASS. Accounting for all of the irrigators in the region as reported in the Farm and Irrigation Survey (NASS, 2012) the margin of error for the survey was calculate to be 4.6% with a 95% confidence interval and 50% Response Distribution. Margin or errors of less than 5% are generally considered a good quality data set.

2.1 Survey Participant Pool

From the pool of the 8,572 identified potential interviewees only 466 irrigators responded and represent the information for this report (**Figure 3**). The pie chart below represent all irrigators who were phone-interviewed – both those who completed the interview (blue), as well as those (purple) who, after starting the telephone process, would later at some point decline on continuing to be interviewed.

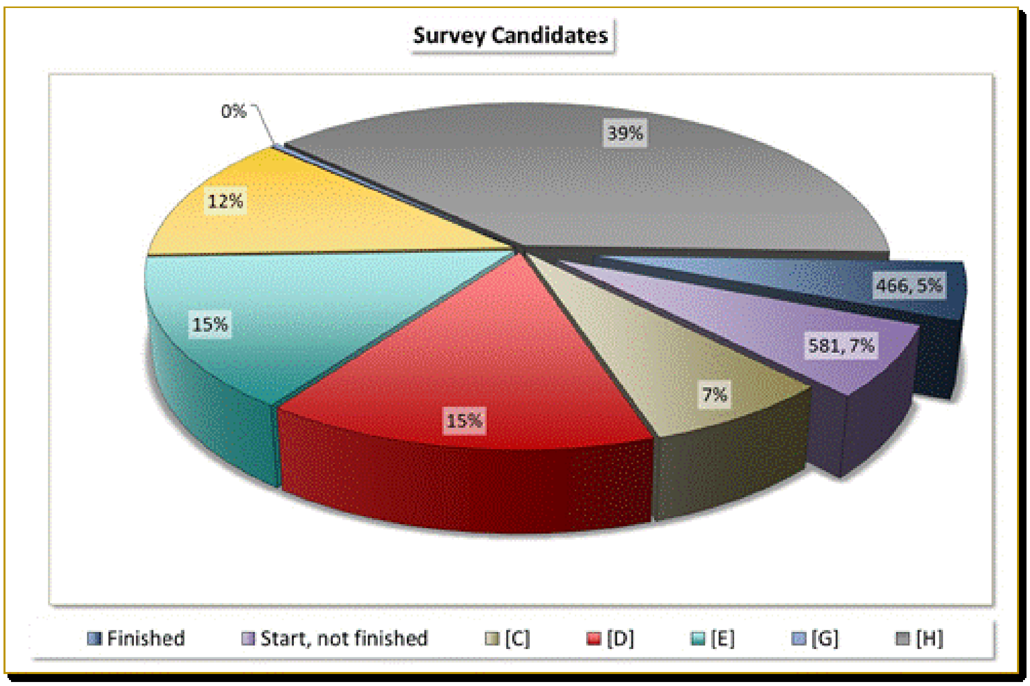


Figure 3. Pie chart showing candidate pool for irrigators to be interviewed. [C] Refused telephone interview; [D] Owner only, didn't irrigate; [E] Retired, health, deceased; [F] Disconnected number; [G] 2nd party refused or communication problems; [H] No answer, busy or couldn't be reached before end of surveying period

A delicate balance existed between gathering as complete and as extensive as possible set of information regarding the irrigation practices of mid-South farmers, versus keeping a person tied up in a long, probing conversation. The survey, in that it was somewhat extensive (over 130 questions), may not only have lowered the number of participants, but may have caused a waning of interest and thoroughness to begin occurring during the latter parts of the survey, thereby, somewhat impacting accuracy. This said, the questions taken earlier in the phone interview may be more reliable.

Irrigators, it should be pointed out, are accustomed to long irrigation surveys; the 17-page Farm and Ranch Irrigation (FRIS) questionnaire, is sent out every ten years by the USDA's National Agricultural Statistics Service.

FRIS, itself is a follow up survey conducted with producers who had indicated in the Census of Agriculture (***CoA***, another survey) that they are involved in some form of irrigation.[8] At this writing, the USDA has just closed the seven-month window for contacting and re-contacting farmers urging them to finish and file their 2017 ***CoA*** questionnaire***.***

Mid-South irrigators may well have felt questionnaire-overload, and the rate of completion in the phone survey might indicate that its overall length impacted the final respondent number by having some participants dropping out before finishing the survey. Data from The Telephone Call Log (**Table 2**) shows that 57% of the farmers who began the phone survey interview, terminated before completing it. **Table 3** shows the state by state result regarding the survey completion rate. In the future, it might be worthwhile to review the terminated interviews to examine at what point in time did survey participants begin to start opting out on finishing with the survey. As intimated, the low survey completion rate also makes one wonder how valid is data that were collected during later parts of the interview process if participants were slowly beginning to feel frustrated.

Table 3. Completion rate for participants that began the telephone survey

Arkansas		Louisiana		Mississippi		Missouri		All 4 States	
Began phone survey		Began phone survey		Began phone survey		Began phone survey		Began phone survey	
370		274		354		49		403	
Completed Survey	Did NOT complete	Completed survey	Did NOT complete	Completed survey	Did NOT complete	Completed survey	Did NOT complete	Completed survey	Did NOT complete
199	171 46.2%	93	181 66.1%	148	206 58.2%	26	23 46.9%	174	229 56.8%

Fortunately, the questions on what crops do you irrigate (***Q3_1*** … ***Q3_7***) occur early (and, establishing this information was very important!). On the other hand, asking, crop by crop, the irrigated 2015 planted acreage in questions ***Q137_1*** … ***Q137_6*** that occurs towards the survey end, at which point, there was close to a 20% fall off in providing an answer to this question. However, just by capturing the number of participants involved in an enterprise, say growing corn, represents "half the battle." Therefore, the ***Q3*** series of questions being at the very beginning of the survey was a windfall. For example, having learned that 63% of the surveyed farmers said that they grew irrigated corn, but some portion of them would subsequently report zero planted corn acreage (as 19% eventually did later in the survey), a situation exists where our <u>participation rate</u> value is probably reliable, but <u>acreage summation</u> value may be a bit jaundiced. Fortunately, other irrigation databases exist and can be cross-referenced to supplement any gaps in the USB Irrigation Survey if we are confident in our participation numbers.

2.2 Participants Interviewed for Survey

In all, 466 irrigators from Arkansas, Louisiana, Mississippi, and Missouri took part in the survey, providing information on a questionnaire through telephone conversations. The size of their irrigation holdings ranged from 5 to 20,000 acres. Their crop diversity ranged from being monocultured to irrigating six different crops.

Table 4 shows the number of participants along with their combined irrigated acreage by state. It also presents, based on USDA/NASS data, the sample's percentage of actual mid-South irrigators (8.5%) and their irrigated

[8] FRIS collects detailed data on irrigation activities and water use on U.S. farms, ranches, and horticultural operations.

acreages (9.1%) captured in the survey. The collective, reported-on acreage for the four main crops was 1,012,776 acres, 11.9% of the approximately 8 ½ million actual acres.

Figure 4 shows a mid-South map reflecting the number and location of survey participants by county.

Table 4. The number of irrigator participants, their acreage, and their % of national totals. [A]

Location	Irrigated Acres			Irrigators		
	USB Survey	USDA/NASA		USB Survey	USDA/NASA	
CORN						
Arkansas	48,143	698,974	6.9%	114	1,497	7.6%
Louisiana	34,030	298,958	11.4%	50	485	10.3%
Mississippi	60,965	521,338	11.7%	106	782	13.6%
Missouri	141,438	245,870	7.3%	24	691	3.5%
All 4 States	161,120	1,765,140	9.1%	294	3,455	8.5%
COTTON						
Arkansas	22,250	246,842	9.0%	34	323	10.5%
Louisiana	9,589	35,673	26.9%	14	67	20.9%
Mississippi	36,350	124,596	29.2%	49	259	18.9%
Missouri	13,150	223,238	5.9%	9	310	2.9%
All 4 States	81,339	630,349	12.9%	106	959	11.1%
SOYBEAN						
Arkansas	268,971	2,592,619	10.4%	190	3,222	5.9%
Louisiana	62,765	263,466	23.8%	56	548	10.2%
Mississippi	202,298	913,850	22.1%	131	1,101	11.9%
Missouri	28,915	333,492	8.7%	26	893	2.9%
All 4 States	562,949	4,103,427	13.7%	403	5,764	7.0%
RICE						
Arkansas	145,873	1,294,506	11.3%	141	2,099	6.7%
Louisiana	32,090	448,885	7.1%	40	716	5.6%
Mississippi	25,805	108,920	23.7%	41	215	19.1%
Missouri	3,600	172,113	2.1%	7	373	1.9%
All 4 States	207,368	2,024,424	10.2%	229	3,403	6.7%

[A] Missouri data from Census of Agriculture (2013); all other data from Farm and Ranch Irrigation Survey (2013).

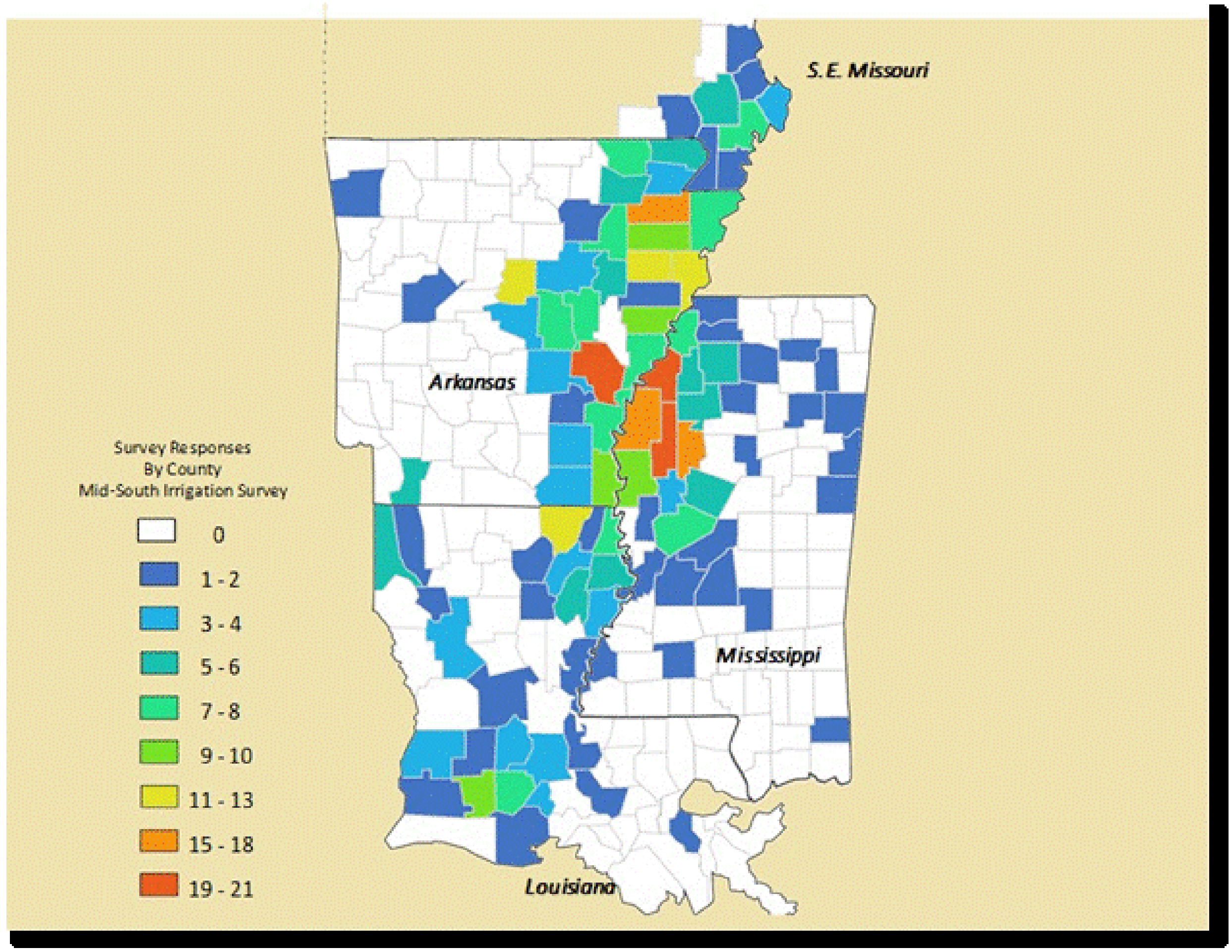


Figure 4. The number of survey participants by county

The final 466 participants providing survey data came from, beginning from the highest contributing state to the lowest contributing one, were Arkansas (199), Mississippi (148), Louisiana (93), and Missouri (26) (Table 5). Although Arkansas had nearly eight times as many respondents as did Missouri, the percentage of irrigators in the two states who finally did complete the survey was actually very similar. In fact, the range of final completed surveys in the four-state pool was just plus or minus 1.2%.

One aspect of the study that survey statisticians from Mississippi State, who were charged with collecting and analyzing data, had commented on earlier was that among the group of four states, Missouri irrigators were the least willing to even begin joining in the survey process. They were a third less likely not to participate, as were the other states on average, and nearly half as unlikely to do so as the most willing of the states (Louisiana) as seen in **Figure 5**. For many of the questions in the survey, the participants were afforded the opportunity to respond *Don't know* or *Don't wish to answer* to the question that was being posed. Missouri irrigators again showed their reticent about providing answers by more frequently using these noncommittal types of answers (at a rate of 1.22 to 1.00).

The region of southeast Missouri (aka, *the Bootheel*) that was in the survey is blessed with massive quantities of groundwater, which also being very close to the surface, allowed it to be inexpensively pumped. Previously, fears of Bootheel farmers that other drier regions of the state might someday wish to regulate, or even divert, part of the southeast water resource, led the Bootheel irrigators to establish the *Southeast Missouri Regional Water District* in 1992. Part of this law stipulated that water users must report annual water use amounts to the state. However, for the most part, irrigators, to this day, do not report their annual usage. This reluctance to report may be due to the fact that landowners still harbor thoughts that the ownership of their water could someday be in jeopardy; this may be part of the reason that a comparatively larger number of Missouri irrigators did not participate in the survey as shown in **Table 5** and **Figure 5**.

Table 5. Total final survey participants by state who provided data and percent of original contacts

Location	Completed Survey	% Completed Survey
Arkansas	199	5.4%
Louisiana	93	4.3%
Mississippi	148	6.7%
Missouri	26	5.1%
All 4 States	466	5.4%

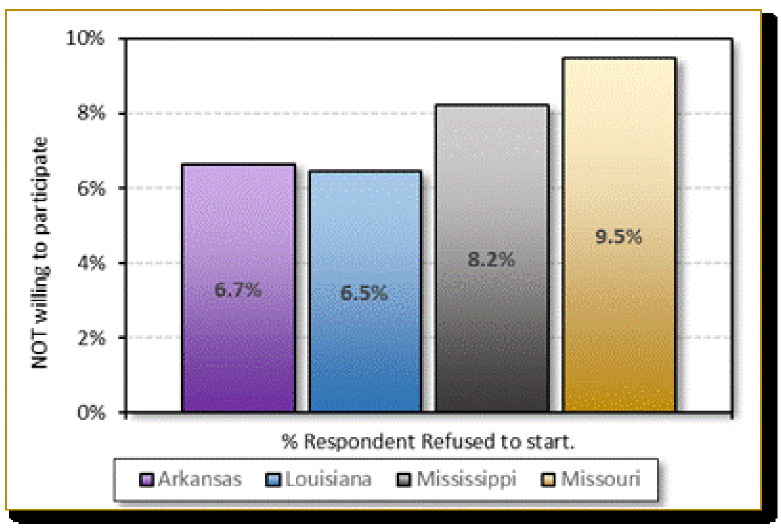


Figure 5. The % of contacted irrigators who refused to participle in the study by state

3 Types of Questions

The phone survey was comprised of up to 256 different questions that could possibly be asked/responded to. However, less than half that number, on average, were asked with a response recorded. Actually, the most questions answered by any one respondent was just 173 (**Table 6**).

Table 6. The number of questions responded to by participants

Region	Average	Max	Min
Arkansas	121.8	173	78
Louisiana	95.6	164	68
Mississippi	113.5	171	70
Missouri	107.4	136	73
All 4 States	113.2	173	68

Less than half the questions collected numeric information, like, number of acres or pumps, years between pivot re-nozzling, % of irrigation coming from groundwater, etc., as seen in **Table 7**. The relative portion of questions being of the "Yes/NO" type was fairly high. Such inquiries are participatory in nature and will be discussed in the next section. One attribute of them is that farmers generally didn't skip over them, but answered them. They normally proceeded a question asking for a numeric value. Questions seeking a numeric value response were generally more likely to be supplied if a "Yes/No" question proceeded it.

The TEXT questions involved the grower choosing from a menu of offered options. They also included questions about menu options that were listed, like " _____ other (Please specify)." The ALPHA / NUMERIC questions involved the year and month an irrigation practice was begun by the farmer.

Table 7. Type of questions asked in the survey.

Type of Question:	NUMERIC	TEXT	YES/NO	ALPHA / NUMERIC (Year / Month)	TOTAL
Number:	109	50	71	26	256

3.1 Participatory Questions

Simple participatory types of questions, as for example: ***Q3_1*** - "*Do you produce (e.g., corn) under irrigation*?", were very quick, effective methods of garnishing information to determine if an interviewee participated in various irrigation-related activities. For questions of this nature, the informant had the options of replying "Yes" or "No" (but he also might choose "Not sure", or not to reply at all). The result from direct questions like these helped confirm the belief that the resultant, established percentile of growers who used (i.e., participating in/with) various irrigation practices was valid. In this series, the respondent was queried --basically asking YES/NO, one after another-- if he had produced under irrigation, six separate crops, plus a seventh of OTHER. Regarding the seven crop choices, there was 100% answering either YES or NO; there was 0% who prevaricated by choosing REFUSED, or I DON'T KNOW, or just leaving the question unanswered. Using the above example of irrigated corn, it was quickly (and we feel accurately) established in the ***Q3_1*** series of questions that 57.5%, 71.6%, 92.3%, and 53.3% of irrigators in AR, LA, MS, and MO, respectively, produced irrigated corn.

Using corn as an example, it was asked about twice again later in the survey.

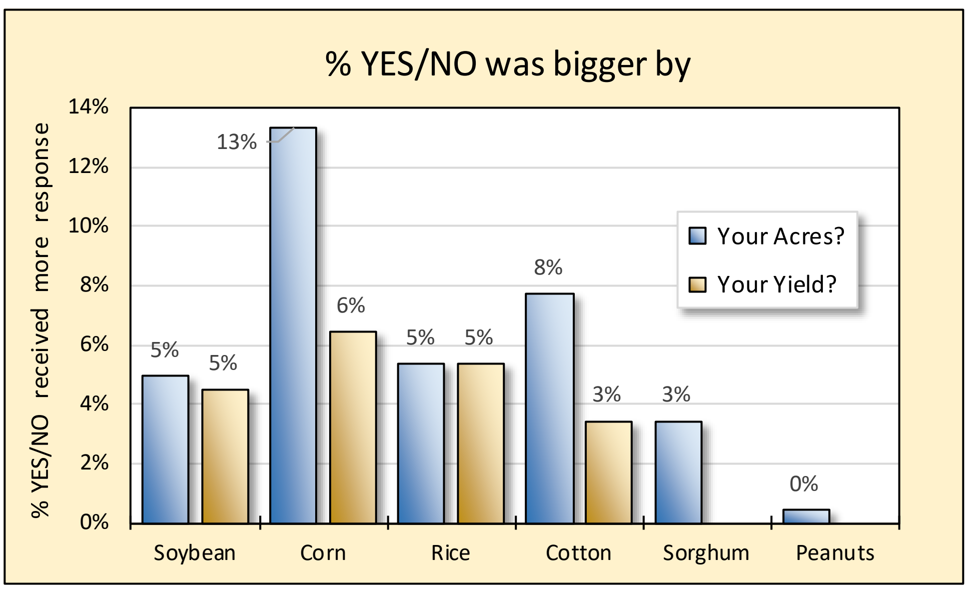
Q137_1 – *"Please tell me how many IRRIGATED acres you had of (corn) in 2015."*

Q143_1 – *"What yield expectation do you have on your farms for (corn, in bushels per acre)?"*

Now, the prevaricating types of responses (i.e., REFUSED, or I DON'T KNOW, or just not answering) had increased from being 0% to now 61% and 39% for the ***Q137*** and ***Q143*** series of questions, respectively. It must also be noted that, following it having been determined that a person grew a particular irrigated crop, up to 200 additional bits of information may have been asked of the interviewee, before the questions of acreage and 2015 yield were posed. Proximity is important.

Since the ***Q3*** types of questions were so straightforward, there was little likelihood that confusion regarding the question had occurred, nor that the given response had been misrepresented. Though this simple form of questioning may appear to "not having much meat on it", these were some of the best interrogatories for garnishing pertinent and useful data on mid-South irrigators.

Nested sets of participatory questions resulted in accurate determination on second levels of related data. For example, question ***Q60***, "*Have you ever used center pivot irrigation for row crops*?" followed by question series ***Q66*** (seen below) provided very accurate information to researchers regarding the configurations of center pivots found in the mid-South. In effect, the percentage of pivots using drop nozzles, end guns, and rotator nozzles becomes accurately known. Additionally, the percentile of pivots able to apply variable rate irrigation and those with corner units is also accessed. These data, in turn, can be parsed even further into state-by-state differences, differences by crops, etc. While no data was collected regarding associated acres, making any acreage information moot, the farmer participation rate is itself accurate.



Do you use any of the following on your center pivots? [Check all that apply]

Q66_1 Drop Nozzles ______
- Yes (-1)
- No (-2)
- Not sure (-3)
- Refused (-4)

Q66_2 End guns ______
- Yes (-1)
- No (-2)
- Not sure (-3)
- Refused (-4)

Q66_3 Rotators ______
- Yes (-1)
- No (-2)
- Not sure (-3)
- Refused (-4)

Q66_4 Variable rate irrigation ______
- Yes (-1)
- No (-2)
- Not sure (-3)
- Refused (-4)

Q66_5 Corner Unit ______
- Yes (-1)
- No (-2)
- Not sure (-3)
- Refused (-4)

3.2 All That Apply/Best Choice Questions

Some interrogatories provided a list of possible choices, either asking the participant to verbally "check the corresponding box" for all the responses that apply, or to select the best choice. An option was provided for the irrigator to write in his own response, should it not have been one on the list proffered by choosing "OTHER". Typically, this questioning method would successfully quantify the importance of about five proffered reasons concerning why/why not adoption had taken place, the funding sources, where growers received information regarding the practice, etc. The open-ended nature of "other" response allowed researchers to learn of alternate, influencing factors not previously recognized.

An example of this line of questioning is seen with questions ***Q17*** (*Do you have a tailwater recovery system* [***TWR***]?) followed by ***Q25*** (*What is the primary reason you started using a* ***TWR*** …?). Regarding the inquiry on whether there was a ***TWR*** on their farm, 152 responded YES. Of the five "canned" reasons provided, the one involving a desire to reduce irrigation costs –nearly half the group chose it-- was the most popular. However, 42% of the respondents chose OTHER, and all 126 in this group went on to elaborate on the reason why. Items mentioned included salinity problems, desiring to use warmer water, etc. Thus, the OTHER option turned out to be an excellent tool for discovering other meaningful factors influencing actions of mid-South irrigators. For example, five of the six responses regarded salinity/water quality as being a driving reason and were from counties in Arkansas that directly abutted the Mississippi River or were located one county away from it –thus a new mitigating factor and its area of influence was confirmed to the PIs.

3.3 Data Input Questions

All the previous inquiries involved choosing from a list of provided responses, while this next category of question type, *data input*, required the participant to input his own value. There were 55 opportunities in the questionnaire where data values could be thus entered. Examples of this type of questioning would be: number of acres? Percent of energy reduction?

Two of the irrigators' special input responses involved data that could appropriately be used in making quantifiable comparisons between groups; these were:

- Estimated energy savings.
- 2015 yield levels for the four main crops.

3.4 Participatory Plus Questions

Also employed were questions of a similar mien to the yes/no types, but based on the received response, would directly link to follow-up, related interrogatories, automatically bypassing any superfluous lines of inquiry. For example, a "Yes" response to the question on having used surge flow irrigation would trigger two questions, year and month ascertaining when the participant first started employing the practice. Other "Yes" responses might lead to questions on why and/or funding sources used. A "No" response might lead to a question on why not. The participatory plus type of question with the most supplementary units of information queried about was ***Q20***, "How many storage reservoirs do you have?", with 32 input slots (up to fifteen reservoirs [surface area and depth], plus year and month first started).

3.5 All-inclusive Question Series

The governing factor concerning all-inclusive question series is that when all of its component elements are summed up, the cumulative value equals the total irrigated acreage of the surveyed participants.

The answers from these question series both involved acreage amounts and were of an all-inclusive nature. When these questions are collectively pooled together with the other companion questions, they then account for 100% of all acres of a participant's farm. The supplied response corresponds exclusively to a specific parameter being enumerated about and a set number of acres is attached with it. For example, if it is reported that X number of irrigated-corn acres are being raised, then that number of acres is exclusively CORN – it cannot be soybean, rice, etc.-- and in summing up the acreage from CORN, and then doing the same for all other of the crops, the participant's total acreage becomes known. Most other types of questions in the survey did not involve *exclusivity*, for example, with the ***Q82*** question series regarding irrigation scheduling (*Which of the following methods do you use to schedule irrigation on your farm?)* nine separate scheduling practices are offered in the questions put forward (**Q82_1** to ***Q82_9***). Results showed that the average mid-South irrigator, employing some form of scheduling methods (7½% of farmers did not or reported "Refused), actually employed 1.62 different methods; the highest number of scheduling tools utilized by a single irrigator was seven out of the nine options. Had the number of acres associated to various scheduling practices been summed up to procure a farmer's actual acreage, double-dipping would have inflated the actual value.

An all-inclusive response can also occur when various separate question series are pooled together, as when total irrigation acres is derived from summing the question series on gravity-, pressurized-, and rice-irrigation methods. Also, some of the all-inclusive series are not referencing the whole farm's total irrigated acreage, but instead, just to rice acreage found on that farm.

The all-inclusive question series found within the survey include:

I. Entire Farm Acreage

1. Crop Being Grown in 2015
    - Corn (Q137_1)
    - Cotton (Q137_2)
    - Soybeans (Q137_3)

- Rice (Q137_4)
- Peanuts (Q137_5)
- Grain Sorghum (Q137_6)

2. Irrigation Methods Being Used
    - Gravity Irrigation Methods
        - Alternate flood & furrow (Q28a)
        - Exclusively flood (Q28b)
        - Continuously furrow (Q28c)
        - Border (Q30)
    - Pressurized Irrigation Methods
        - Drip (Q32)
        - Regular center pivot (Q62)
        - Towable pivot (Q63)
    - Rice Irrigation Methods
        - Precision grade (Q97_1)
        - Contour levee (Q97_2)
        - Zero grade (Q97_3)
        - Row-water (Q97_4)
        - Pivot (Q97_5)

3. Various Land Surfaces on the Farm
    - 0-Grade (Q47_1)
    - Warped surface (Q47_3)
    - Precision Grade / Constant Slope (Q47_2)
    - Not leveled (Q47_4)

II. Farm's Entire Rice Acreage

1. Rice Grown in 2015
    - Rice (Q137_5)
2. Rice Irrigation Methods Being Used
    - Precision grade (Q97_1)
    - Contour levee (Q97_2)
    - Zero grade (Q97_3)
    - Row-water (Q97_4)
    - Pivot (Q97_5)

3. Rice Watering Methods Being Used
    - Continuous Flood (Q103_1)
    - Alternate wetting and drying (Q103_2)
    - Straight Head Drain (Q103_3)

4. Various Land Surfaces on the Farm x $\left(\frac{Rice\ acreage}{Total\ crop\ acreage}\right)$
    - 0-Grade (Q47_1)
    - Warped surface (Q47_3)

- Precision Grade / Constant Slope (Q47_2)
- Not leveled (Q47_4)

3.6 Regarding Number of Questions in Survey

In conclusion, for the main *USBIS*, the various questions, plus their add-on additional requests for further detail, yielded 259 columns of data being in the questionnaire matrix. The rows in the matrix, which represents individual respondents, was 466, plus one header row with the question number.

There were, in addition, two auxiliary studies that were based on additional data that was collected during the interview process. Knapp, et al. (2018) sought to quantify irrigators' willingness to pay for irrigation water when groundwater is scarce. Some questions investigated the impact on farmers adopting a variety of ***IBMP***s based on whether that farmer, having in the last five years, seen a neighbor using it, heard a presentation, etc.

4 Irrigation Data Collected

In the survey, irrigation-, farm husbandry-, and demography-related data all were collected. Demographic data included location (state and county) and socio-economic information, such as, years of farming experience, education, net family income, etc. These demographic factors provide means for the study to investigate how irrigation-related parameters might <u>differ among groups</u> (e.g., by states, owner/renter, pivot/surface irrigation, etc.) or <u>differ within groups</u> (different farm sizes, years of experience, income levels, educational levels, etc.). Full interstate comparisons for all mid-South states was partially hampered by the small number of Missouri responses (n=26), coupled with its relatively high level of "Refused" and "Don't Know" responses from the *Show Me* state.

One among-groups-type of comparison involved the irrigated crops being grown. Northern Economics, Inc. (2017) had used the mix of crops grown to establish ten sub-groups which they then compared. The *USBIP* focuses on two crop groups. First, rice/non-rice growers is a natural differentiation to investigate because of the inherently different practices involved in how they are irrigated. Differences were found between the two groups. Secondly, since this project received its primary support from the United Soybean Board, soybeans were of interest to PIs. Approximately 85% of study group raised soybeans (making it the most frequently identified irrigated crop to be grown); the PIs were as interested in examining the 15% who did not grow soybeans, as they were in the majority of producers who did so, to see if there might be factors indicating why soybeans were not grown.

Table 9 breaks down the various lines of questions in the survey into associated subgroups, e.g., type of system, energy, social factors, agronomic practices, etc.

4.1 General Irrigation Questions

As mentioned, both irrigation- and demography-related data were collected. Demographic data included location and socio-economic information, such as, stake-holder status (operator or owner operator), years of farming experience (which in turn, reflects age of interviewee), education level, household income, and farm size. Also, information concerning the respondent's feelings regarding the possibility of water shortages existing on either his farm specifically, or his state generally, was inquired about; this was followed with a query concerning water level changes (lowered, rose, or stayed the same) at his farm.

Regarding agronomic practices, information on main crops and cover crops was asked about. Information, also, on various farm practices, such as, deep tilling, liming, and use of PAM was collected, as was, land-forming status (zero grade, constant slope, or warped slope). Practices involving water and energy savings (e.g., such as tail water pits and use of storage reservoirs) was also investigated. The number and type of power units was queried about, including the use of specialized pump equipment (timers and water meters). Information was gathered on type of irrigation systems used. Along those lines, pertinent additional information concerning the various types of irrigation systems was gathered. For example, pivot users, besides being queried concerning the type of unit (i.e., fixed or towable), were also asked about: their use of end guns, drop nozzles and rotator nozzles; the frequency of sprinkler package replacement and the presence of variable rate irrigation capability and use corner units.

In addition, irrigation practices, specifically related to rice production, were gathered.

4.2 Areas of Focus for the *USBIP* Investigation

Two special areas of focus in the ***USBIP***, differentiating it from many irrigation surveys, were (1) the focus on ***IBMP***s and (2) farmer adoption histories. The former area was atypical in that besides just user/acreage data being reported, many other aspects of ***IBMP***s were collected (e.g., funding sources, reasons why/why not adopted, energy savings, time when first adopted, etc.). The latter aspect was special in that it was unique information not known to have been published before.

4.2.1 Irrigation Best Management Practices (*IBMP*s)

Of special interest in the *USBIP* survey was information regarding use of irrigation best management practices (***IBMPs***), such as, irrigation scheduling, computer hole selection for poly-pipe header lines, etc. On some of the ***IBMP***s, additional information was also collected for reasons why/why not a practice was adopted, funding method for securing the investment, and when the practiced was first begun. In some cases, the farmers' estimate of percent decrease/increase in energy use stemming from some of the various ***IBMP***s was also collected.

The use of <u>% change in the operating time</u> of pumping units after adopting an ***IBMP*** was the metric used to estimate incurred energy savings. It is an excellent choice for the evaluative index measuring change in energy consumption. It is applicable for a wide assortment of irrigation scenarios, whether they are "high energy" or "low energy". Time is a commodity that farmers generally stay aware of (how long it takes water to reach the end of the field, hours to make a pivot circle, etc.) Also, many times, it is verifiable, and should the irrigator be unsure concerning actual times involved, backup resources often exist, such as monthly electrical bills, runtime odometers on equipment, etc.

Data had previously been analyzed for a sub-level study regarding farmers' willingness level to commit economic resources on ***IBMPs*** to save water (Knapp et al, 2018) and is reported separately. ***IBMP*** adoption as influenced by the participant knowing, within the last ten years, someone who employed this ***IBMP*** was also ascertained, and is also presented elsewhere. However, both lines of enquiry were done using only the data from Arkansas. Our study's ***IBMP***s included:

- On-farm Water Storage
    - Tailwater recovery system and Storage reservoirs

- Furrow / flood Irrigation
    - CHS (e.g., PHAUCET/Pipe Planner)
    - Surge irrigation
    - End blocking
    - Cutback
    - MIRI (Multiple inlet irrigation for rice)

- Land Surface Improvement
    - Zero grade
    - Zero grade + continuous rice?
    - Precision Leveling
    - Precision Leveling + MIRI
    - Contour levee + MIRI

- Soil Improvement
    - Gypsum
    - PAM

- Deep Tillage

- Irrigation Scheduling, in general
  - Soil moisture sensors
  - ET or Atmometer
  - Computerized Scheduling
    - Woodruff Charts

Recall that the ancillary data on factors associated with the various ***IBMP***s was not uniformly collected. In some cases, just a single piece of data was collected (Do you have any associates have used this practice?). Surge flow was the ***IBMP*** that had the most associated data points about it collected, eight.

The three following tables help put the information regarding the IBMPs in various perspective angles:

- Table 6 Types of IBMPs categorized into broad groups.
- Table 7 Questions by thematic categories.
- Table 8 Specific information collected and its question number.

Table 8. Types of IBMPs categorized into groups, plus information on whether start time & acreage amount (B) was collected.

Water/Energy Conservation	Enhancing Surface Irrigation Performance	Enhancing Surface Irrigation Performance (Rice)	Enhancing Pivot Irrigation Performance	Enhancing Overall Irrigation Management
- Storage Reservoirs (B)	- Tail Water Recovery (B)	- Zero Grade (B)	- Changing to pivot	- Soil Moisture Sensing (B)
- Flow Meters	- Computerized Hole Selection (B)	- MIRI – contour (B)		- ET gauges (Atmometer) (B)
	- Surge Flow (B)	- MIRI - precision (B)		- Computer Scheduling (B)
	- Precision Leveling (B)	- Alternate wetting and drying for rice irrig.		- Woodruff Irrigation Charts (B)
	- End Blocking			- Deep Tillage
	- Cutback irrigation			
	- Furrow diking			
	- Changing back to furrow from pivot			

Table 9. Questions by categories in the irrigation survey.

Demographics	Crops	Irrigation	Irrigation System Enhancements	Soil Enhancements	Irrigation Best Management Practices	Energy
General Background	**Crops Farmed**	**Irrigation Methods Used**	**Land Surface Treatments**	**Treatments**	**Various IBMPs**	**Energy System Types**
Land ownership Irrigated crops County & state residence Water source used Depth to water Perception of water severity	Corn Cotton Soybeans Rice Peanuts Grain Sorghum	Flood irrigation Furrow irrigation Border irrigation Microirrigation [A] Pivot irrigation [B] Changing of method (Pivot → Furrow)	Tailwater recovery system Zero grade Precision Grade / Constant Slope Warped surface, OptiSurface Not leveled	Application of gypsu Application of PAM Deep tillage Depth ripped to Tool used Cover crop use	Tailwater recovery system Storage reservoirs Computerized hole selection Surge irrigation Irrigation scheduling method MIRI Zero grade Deep tillage End blocking Center Pivot	Fuel source used
Social Factors	**Expected Yields**	**Rice Irrigation Methods**	**Surface Irrigation Enhancements**		**Aspects of the IBMPs**	**Equipment**
Conservation programs involved in Education level Age Ag school Income Years of farming experience	Corn Cotton Soybeans Rice	Precision grade Contour levee Zero grade Row-water Pivot	End blocking Cutback irrigation Deep Tillage CHS MIRI		Use this particular IBMP? Acreage When started Why it's done Why not done Funding sources Amount of energy saved	# of pumps Timer on pumps Flow meters present? Flow meters - types
		Rice Irrig Application Methods	**Pivot Irrigation Enhancements**		**Scheduling Methods**	**Energy Savings**
		MIRI Continuous rice Alternate wetting and drying Straight Head Drain Rice scheduling methods	Drop nozzles End guns Rotators Variable rate irrigation Corner Unit Nozzle repackaging		Computer program Woodruff charts ET or Atmometer Soil moisture sensor Other methods	Expected energy savings from IBMPs

[A] Buried or surface.

[B] Fixed or towable.

Table 10. Part of the Information collected regarding various Irrigation Best Management Practices (Col. A); it includes Date Practice was Adopted (Col. C) and the Expected Energy Savings (Col. J). The question number is indicated.

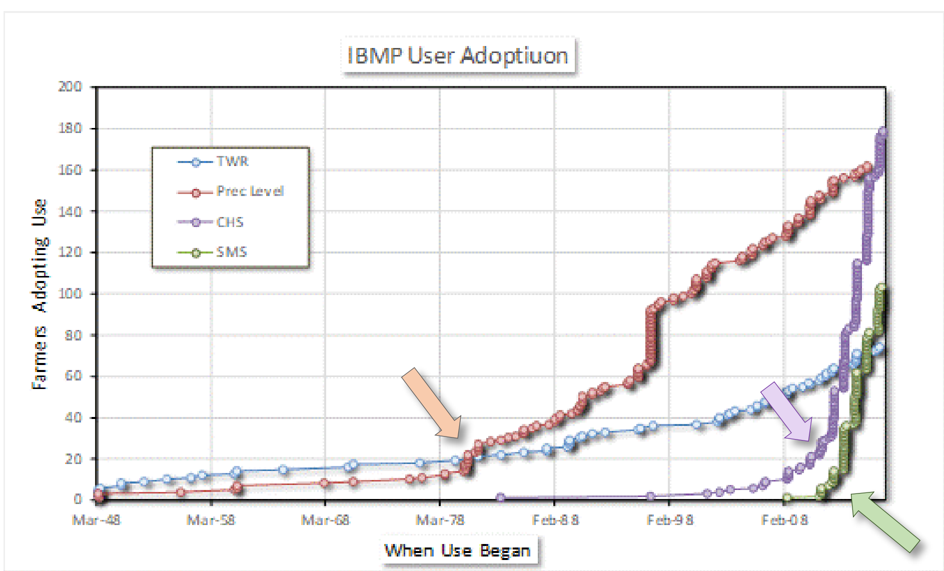
Practice	Do You Use?	When Started?	Type of Practice	Relates to Irrigation Method	Acres?	Funding Methods?	Why done?	Why not done?	Energy Savings?	Associates [B] have used this practice	Additional Information
(Col. A)	(Col. B)	(Col. C)	(Col. D)	(Col. E)	(Col. F)	(Col. G)	(Col. H)	(Col. I)	(Col. J)	(Col. K)	(Col. L)
Tail Water Recovery [A]	Q17	Q19_1	Water / energy conservation	Furrow	Q18	Q26_1 - 5	Q25	---	Q105_1	Q133_02	---
Storage Reservoirs [A]	---	Q24_1	Water / energy conservation	Surface	---				Q105_3	Q133_03	• Number (Q20) • Surface Area / Depth (Q22_1a – 15d)
Computerized Hole Selection	Q36	Q38_1	Furrow Irrigation Enhancement	Furrow	Q37		Q39	Q40	Q105_4 [C]	Q133_04	---
Surge Flow	Q41	Q43_1	Furrow Irrigation Enhancement	Furrow	Q42	Q45_1 - 4	Q44	Q46	Q105_5	Q133_05	---
Pivot back to Furrow: $(P \rightarrow F)_1$ $(P \rightarrow F)_2$	Q57 Q67	Q58_1	Energy conservation	Furrow	Q59 Q68	---	---	---	---	---	---
Using Pivot	Q60 Q61	Q64_1	Pivot Irrigation Enhancement	Pivot	Q62 Q63 Q97_5 (rice)	---	---	---	Q105_09	Q133_01	• Sprinkler Pack. Freq. (Q65) • Drop nozzles (Q66_1) • End gun (Q66_2) • Rotators (Q66_3) • Variable rate irrig. (Q66_4) • Corner units (Q66_5)
Soil Moisture Sensing	Q82_9	Q83_1	Irrigation timing & amount	All	Q84	---	---	---	Q105_10	Q133_10	• Type / brand (Q85)
ET gauges (Atmometer)	Q82_6	Q86_1	Irrigation timing & amount	All	Q87	---	---	---			---
Computer Scheduling	Q82_2	Q88_1	Irrigation timing & amount	All	Q89	---	---	---			---
Woodruff Irrigation Charts	Q82_3	Q90_1	Irrigation timing & amount	All	Q91	---	---	---			---
Precision Leveling	---	Q49_1	Surface Irrigation Enhancement	Surface	Q47_2 + Q47_3 Q97_1 (rice)	Q51_1 - 4	Q50	Q52	---	Q133_07	---
Zero Grade	---	Q98_1	Surface Irrigation Enhancement	Surface	Q47_1 Q97_3 (rice) Q97_6c (rice continuous)	Q99_1 – 5	---	---	Q105_06	Q133_08	• Continuous Rice (Q97_6c)
MIRI – contour MIRI - precision	--- ---	Q100_1	Surface Irrigation Enhancement	Surface	Q97_6a Q97_6b	---	Q101	Q102	Q105_02	Q133_11	---
Deep Tillage	---	No starting date collected.	Surface Irrigation Enhancement	Surface	Q54_3 Q92_3	---	---	---	Q105_07	---	---
End Blocking, cutback irrigation, or furrow diking	--- --- ---		Furrow Irrigation Enhancement	Furrow	Q54_1 Q54_2 ----	--- --- ---	--- --- ---	--- --- ---	Q105_08 --- ---	Q133_09	---
Flow Meters	Q72		Irrigation amount (Water / energy conservation)	All		---	---	---	---	Q133_06	---
Alternate wetting and drying for rice irrigation	---		Surface Irrigation Enhancement	Surface	---	---	---	---	---	Q133_12	---

[A] In-depth economic evaluations done regarding these parameters (C.f., Northern Economics, Inc. 2017).
[B] A separate evaluation of these practices. [C] Error occurred in processing data, so was not collected.

4.2.2 Adoption History

In the querying process, the respondents were asked when they first started using thirteen different types of ***IBMP***s, which allowed adoption curves to be developed. This unique, temporal line of inquiry, seldom seen, enhances our knowledge regarding various irrigation practices in the region. This information can provide an understanding regarding impact derived from extraneous factors. For example, does the change in the shape of the adoption rate curve coincide in the past with the initiation of any major irrigation education programs? Or did practice uptake increase rapidly when certain other events had taken place?[9]

Developing the time-based adoption history of these ***IBMP***s was built on farmer-provided start-up data (month and year) of first using these practices; concomitant data was the current acreage involved. These two data having been collected, detailed insight into the history of various ***IBMP***s as they were first introduced into local irrigation communities, as well as its rate of adoption, can be constructed. This is a unique contribution provided by the ***USBIPR***. **Figure 6** is a graphic depicting when mid-South farmers began using four different, regionally important ***IBMP***s, tailwater reservoirs (TWR), precision leveling (Prec Level), computer hole selection (CHS), and soil moisture sensors (SMS), which together sketches a history of mid-South irrigation. TWR and Prec Level were first used after WW2 but didn't increase much in popular use until the 1980s. CHS had rapid growth in adoption after 2010; it initially was developed by Doyle Burch and others of the NRCS as a DOS-based program in the 1970s, but later took off in user adoption after the private industry took a leadership stake and developed and supported a CHS program. In 2011, Delta Plastics released a web-based CHS program, called Pipe Planner™ which has become the mainstay of CHS design in the region. Fully supported by Delta Plastics, the company originally charged on a per acre basis for using the program but in 2014 made it free to use, while still supporting the program with full time dedicated staff. During this same period the University of Arkansas and Mississippi State University had formal considerable efforts focused on CHS, Surge, and SMS demonstrations and related educational programs. Cotton Incorporated has also been funding some SMS research and outreach during this time period. Arrows in the graph indicate the time when adoption rates greatly increased. TWR rate of growth was fairly linear.



[9] The increased use of computer hole selection, with its mercurial change in adoption, appears to be related to joint educational efforts that took place around 2012.

Figure 6. Timelines of participants' adoption of four different ***IBMP***s common to the Mid-South.

As mentioned, besides information on when a practice was first begun to be used, in some cases, other additional information regarding practices was collected, such as: on acreage, why/why not was the practice employed, funding sources, and estimated energy savings. Table 10 lists ***IBMP***s and the ancillary information pertaining to it that was collected. Table 8 lists the ***IBMP***s categorized and into broad groups: Water/Energy Conservation, Enhancing Surface Irrigation Performance, Enhancing Surface Irrigation Performance (Rice), Enhancing Pivot Irrigation Performance, and Enhancing Overall Irrigation Management.

Since respondents supplied both locale (state and county locations) and MO-YR information data regarding ***IBMP*** adoption, ***USBIR*** influences can be both time- and geo-referenced. Regionality differences could be inferred if the curve calculus changes within certain states, or areas of a state, but not in others. <u>Where</u> was adoption more likely to occur?[10] Thus, the impact stemming from influences from outside factors/entities, such as aquifer characteristics, salinity levels in groundwater, specialized irrigation service companies (e.g., multi-slope land-leveling, etc. companies), local management groups, etc. may be inferred and their footprints witnessed on reviewing adoption rate curves.

Also, previous information derived from the Northern Economics Study regarding the adoption of some of these ***IBMP***s as influenced by the participant's awareness of that ***IBMP*** being used by any associate within the last ten years has been reported.

Incidentally, when an ***IBMP*** interrogatory included both a query on adoption time and on acreage amount, user response was increased. In analyzing the survey results, it became obvious that for some reason, a few participants were not reporting 2015 crop acreage amounts ("Don't know" or "Refused"), or just reporting "0 acres", when indeed it was likely that some acreage was indeed involved. However, if a participant had taken the time to record the year (and even the month) for an ***IBMP*** (as in the example seen in Text Box XX involving CHS [one of 13 like it in the survey]), he was more likely to report 2015 crop acres and, of course, was using CHS on his farm.

Q38

When did you start using computerized hole selection?

Q38_1	Year	______
Q38_2	Month	______

Text box xx.

The ***IBMP*** interrogatory involved <u>time started using</u> and <u>current acreage</u>. If a grower didn't provide information for one, or even both, of the data points then the accumulated adoption curves were "filled in" using this

[10] Regarding "where", two localities/entities may be positively influencing the use of ***IBMP***s. First, a head office of OptiSurface being located in Jonesboro, Arkansas. Secondly, activities of the Yazoo water management district in west central Mississippi has a bearing on the employment of water meters.

following algorithm. If the month response was “Don’t Know”, June was chosen. If the year response was “Don’t Know”, then the average year value for that practice and that state was used. If the acre response was “Don’t Know”, again the average reported acreage for that practice and that state was used. In some instances, 0 was reported as the acreage and this was overridden with the mean value from the other respondents on that practice and that state.

Time is presented on the X-axis of the adoption graphs. The Y-axis represents the:

- Farmers in the survey using the practice.
    - ~ (or % of farmers using that practice).
- Acreage in the survey where that practice is employed.
    - ~ (or % of acreage employing that practice).

Since the ***USBI*** survey only captured about 10% of total mid-South irrigators and irrigated acres, the actual values seen in these graphs for farmers using and acres involved, are not regional values. However, data from Table 4 regarding collected data relative to regional sums can be employed in estimating users and acres in the region.

4.3 Tallying Mid-South Irrigated Acreage

Although, just how many acres were being irrigated by each of the 466 survey participants was of paramount importance in the study, respondents were never directly posed with one single, specific query in this regard. Instead, quantification of an individual's irrigation holdings was determined from the responses gained from several lines of inclusive questioning, the sum from each of these individual topic areas being equivalent to the farmer-operated irrigated acres (c.f., ***3.5--All-inclusive Question Series***).

The original topic areas that served as a summation methods of irrigated acres were:

- The participant's irrigated crop acreage in 2015
- The number of acres individual participants had of the different types of irrigation systems in 2015.

Later analysis of the *USBIS* data showed that two additional methods of summation were possible:

- The reported acreage for the different types of surface finishes on their farms.
- The number of irrigation pumps owned by the individual.

All of these four datasets consisted of a column made of 466 datapoints (some datapoints being a numeric value and some were blank nulls) which corresponded to each participant's irrigated acres for his farm. Of course, all four methods should be in close agreement with one another, both in terms of their collective sums, but also as, the individual farm-by-farm values for each of the 466 participants. **Table 11** shows acreage amount, n and Ratio value (Method Acreage / Crop Method acres).

Table 11. Irrigated Acres Summation Methods showing Acres, n and Ratio Value

Summation Method	Designation	Acres	n	Ratio
∑ Crop Method	**Acres$_{CG}$**	1,024,113	453	1.00
∑ Irrig Systems Method	**Acres$_{IM}$**	1,206,406	441	1.18
∑ Land Surfaces Method	**Acres$_{SF}$**	963,487	439	0.94
∑ Pump Supported Acreage Method [A]	**Acres$_{P}$**	1,090,734	442	1.07

[A] Eight samples of values > 500 acres/pump not included in algorithm.

Additionally, since rice was a crop that was treated differently from the other five crops, total acreage summations of RICE for each participant can be determined by using the above methodologies. In addition, stemming to the fact that an additional rice-only question had been posed in the questionnaire, a fifth rice-only summation was possible, and was based on the supplied acreages for different rice water management methods.

4.3.1 Multi Methods Afforded for Totalizing Survey Acreage

Since there are four different manners to sum the survey's irrigated acreage, a concept of ***dual method*** (or even **multi-method**) is in play. This dual method concept becomes a failsafe and assists in factchecking within the whole dataset. Sums, as well as paired data points, for any two methods should be in close agreement. However, if merely the overall acreage amounts using any two methods, say acres of irrigated crops (***$Acres_{CG}$***) versus the acreage amount for all irrigation systems (***$Acres_{IM}$***) are used, and the amounts should appreciatively differ from one another, the genesis of the error would not be known. In fact, there might be a situation where the totals might be close in agreement, but only because there was both under- and over-reporting that cancelled things out –which is the case in those two datasets where one participant overshot acreage by 12K, while another undershot acreage by 12K.

The dual method allows individual farm irrigated acre values to be compared, datapoint by datapoint, between two datasets, in effect, it is the difference between a bar graph and a linear graph. The advantage of the latter is that by merely examining the resulting image, one can quickly pinpoint where data problem areas might exist -- the outlier points. In addition, if a third dataset (or even, a fourth) is also available then crosschecking becomes a possibility, and substituting a modified value could be contemplated.

A brief discussion follows regarding using just the two standard methods, *crop-based* versus *irrigation method-based* tallies to determine the participant's irrigated acreage. However, it should be kept in mind that in the process of collecting the number of acres employed using various particular irrigation methods, *user participation rate* is also collected. The percentage of users is thought to be a better metric then involved acres, as discussed earlier (***18.5 Consistency within Survey Results***), so minor differences between the crop-based and the irrigation method-based acreage tallies should not become too problematic. Nonetheless, a discussion of the two tallying methods follows. Potential solutions for rectifying differences is discussed in the appendices.

The survey was designed to collect information on the participants' overall irrigated acreage from two previously discussed main venues:

- based on the major irrigated crops being grown in 2015 (**$Acres_{CG}$**).
- based on the method of irrigation being used in 2015 (**$Acres_{IM}$**).

The former compilation method, based on only six irrigated crop acres, comes from a singular source, the ***Q137*** series of questions regarding the six crops (corn, cotton, soybean, rice, peanuts, and grain sorghum) that was queried about nearly at the very end of the interview:

"Please tell me how many IRRIGATED acres you had of each of the following crops in 2015."

On the other hand, information regarding acreage based on the irrigation methods employed on the farm, ***$Acres_{IM}$***, is derived from summing responses from several sub-groups of questions involving three broad irrigation categories:

- Gravity irrigation methods for field crops (***GI***).

- Pressurized system (i.e., pivots and drip) irrigation methods for field crops (***PS***)
- All various rice irrigation methods (***RI***).

Totaling the results from these three irrigation sub-categories provides the ***Acres$_{IM}$*** value.

NOTE: *Again, the total acreage derived by summing crop acreages (**Acres$_{CG}$**) should be similar in value to the summation values based on methods of irrigation (**Acres$_{IM}$**).*

Later researchers were also able to determine and validate participants' irrigated acreage through two other avenues, surface finishing (***Acres$_{SF}$***) and pump servicing capacity (***Acres$_{P}$***), both will be discussed more below. However, for the main part, these newcomers did not supplant the two main approaches, ***Acres$_{IM}$*** and ***Acres$_{CG}$***, that Northern Economics, Inc had first developed.

4.3.2 SUMS or PAIRED VALUES for Tallying

The dual method comparison will allow the use of two formats for determining the participant's irrigated acres: first, as summed values (the normal approach), and secondly, by comparison of the sum of all independent, paired data points. Total sums should be equal with either method, or nearly so; PLUS, the individual (up to 466) paired values, should likewise be equal, each to its own partner value. Divergent individual values among paired datapoints reflect error somewhere.

The first inclination in evaluating the level of agreement/fit between various irrigated acre tallying methods involved comparing their overall calculated sums, as done by Edwards in 2016. There, the *USBIS* sum of ***Acres$_{CG}$*** acreage for the 466 participants of all four states was found to equal 1,024,113 acres, while the sum of the ***Acres$_{IM}$*** acreage method for these 466 same farmers has a value of 1,513,593 acres, ergo the 1.50 reported ratio.

Turning from the former sum method to the paired value method, entails using up to 466[11] *dependent, paired* values that are summed. Changing from the macro comparison approach that used bulk, summed values to, instead, using a micro level approach, in which, dependent pairs of values from each reporting participant are both compared to each other and also summed for use, affords the opportunity to identify (and possibly, to correct) outliers that have divergent values from each other. The downside is, that for those pairs of datapoints where one of the two points is missing, the extant single valid one must be discarded.

The pros and cons of the two methods are seen below,

Table 12. Summation Methods for Irrigated Acres

Bulk Summation Method		Paired Values Summation Method	
Pro	Con	Pro	Con
· Easiest concept · Uses all n values · Good for simple $\bar{X}$ · User participation rate better as n is greater	· Won't show data inconsistencies	· Create graphs (see outliers) · Check 3rd sum method to replace · Can sub-size data (e.g., by size) · More sophisticated stats	· Decrease n (both pairs needed)

[11] The actual number of dependent ***Acres$_{CG}$*** and ***Acres$_{IM}$*** usable pairs available for totalizing was less than 466, and is logically limited to be the smaller N-value of the paired sets of data.

4.4 Separate Crop Domains

The crops of interest in the *USBIP* study were limited to main ones grown under irrigation in the mid-South, which included these six: corn, cotton, soybeans, rice, grain sorghum and peanuts. However, yield information was only collected for just the first four listed.

Rice versus non-rice field crops were dealt with in different ways because of the questions that had been asked. For example, in determining the methods (and corresponding number of acres) used by the participant to water his rice, the questionnaire proffered these five choices: a) Precision grade, b) Contour levee, c) Zero grade, d) Row-water, and e) Pivot. For the non-rice field crops the choices offered were a) Furrow, b) Flood, c) Border, d) Drip, e) Fixed Pivot and f) Towable Pivot. Because of this dichotomy, the CROP domain is a bit more heterogenous and now can be broken down into three separate demarcations (and when the null set is considered, it is four), allowing participants to be grouped as:

- Both FIELD CROPs and RICE are grown.
- Only FIELD CROPs grown (no rice).
- Only RICE grown (no other crop is grown)
- Null set (no information provided for any planted crop)

Information regarding these groupings can be seen in **Table 13** and **Figure 7**. Information on demarcation categories can presented as acreage involved, as well as, participants in the category. The first two crop domains above are by far the biggest, and together represent 90% of users and 97% of acreage.

Table 13. Domains by crops grown.

Item	Row Crops; YES Rice: YES	Row Crops; YES Rice: NO	Row Crops; NO Rice: YES	No crop data was supplied	TOTAL (full report)
n =	174 37%	249 53%	30 6%	13 3%	466 100%
∑ acres (acres)	545,797 53%	454,076 44%	24,240 2%	--- [A]	1,024,113 100%
Average (acres/farm)	3,137	1,824	808	--- [B]	2,261

[A] Estimate = 4,682 acres/farmer X 13 = 60,860 acres

[B] Estimate = 4,682 acres/farmer (based on average $\boldsymbol{Acres_{IM}}$ and $\boldsymbol{Acres_{SF}}$ values for the appropriate datapoints)

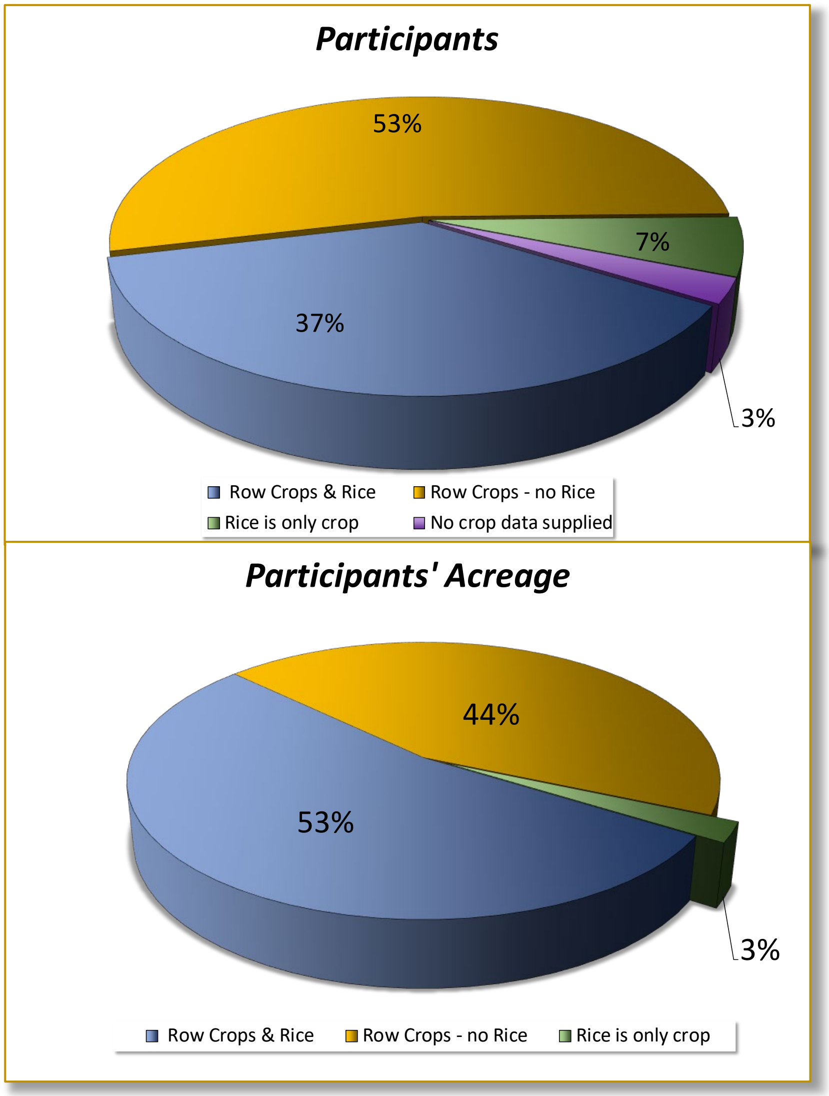


Figure 7. Crop domains percentages by participants and total acres.

Though this notion of crop domains seems to be a case of "much ado about nothing" it does bear some significance because the RICE dataset may have some of the "best quality" data, as witnessed by the rice acreage dataset having a correlation coefficient of 0.996 to the dataset of rice watering strategies. Also, rice has one additional track whereby 2015 planted acres is able to be correlated with, i.e., rice water management practices.

The non-rice field crop domain category was constructed by stripping off the RICE data set values from what is actually the complete dataset, i.e., the ALL RICE & NON-RICE FIELD CROPS data set, thus creating three domains which subsequently causes decreases in domain size. Also, should a data point or two be outliers, splitting the full dataset basically into smaller blocks of 38%, 55% and 7% of the former size, may isolate the problem datapoint.

4.4.1 Crop-Specific Results

Other than for rice, the direct impact of ***IBMP***s on specific crops could not specifically be determined. In the study there was difficulty in trying to establish crop-specific impacts since many of the questions and responses were aggregated. For example, the ***Q105*** series of questions asks information on incurred energy savings stemming from ten different ***IBMP***s:

> *For each of the following changes you've made to irrigation, by what percent did pumping time decrease (if any) as a result of the change?*

One choice option was a generic response about *irrigation scheduling* (e.g., computerized scheduler, soil moisture sensors, canopy temperature, ET or Atmometer). The *USBIS* results indicate that users of scheduling reported an average energy savings of 13%. Now, two logical follow-up questions would be: what particular scheduling method? and on what crops?

In previous questioning, the acreage amount for three of the four methods was asked about. Also, in regards crops, both the acreage and 2015 yield were queried about. From these data paths logical estimates might be able to be made (c.f., ***15.10 - Irrigation Scheduling***), still the lack of crop-specific specificity can be limiting. Therefore, being able to separate responses into at some smaller generic crop groups could be helpful.

5 Irrigated Acreage in the Study

The amount of irrigated land that participants owned could be individually totalized, and then the whole group's collective acreage summed up, providing state and regional totals of irrigated acres using any one of four summation strategies. These main avenues for tallying were:[12]

- The acreage of the 2015 irrigated crops on the farm (**Acres$_{CG}$**).
- The number of acres of the different types of irrigation systems in 2015 on the farm (**Acres$_{IM}$**).
- The number of acres of the different land surfaces on the farm (**Acres$_{SF}$**).
- The number of acres estimated by the number of irrigation pumps on the farm (**Acres$_{P}$**).

Not every producer had supplied enough data for all four methods to be possible (although 87% had). In 3% of the cases there had not been enough supplied information to develop even a single summation calculation. **Table 14** shows the number of possible summation methods available for totalizing the survey participants' irrigated acres.

Table 14. The number of available methods by which to calculate respondents' irrigated acreage

Region	Number of different methods available to calculate total irrigated acres				
	4	3	2	1	0
Arkansas	177	11	9	1	1
Louisiana	75	5	8	0	5
Mississippi	132	6	4	1	5
Missouri	21	2	0	1	2
4-State	405 87%	24 5%	21 5%	3 1%	13 3%

These four main datasets are each comprised of a potential of 466 farmer-specific points of data; the unit of measurement for all four is acres. In a perfect world, not only would the sums of all four sets of data be equal, but there also would be unanimity among each of the four values for each of the 466 potentially different, farmer-specific data points. However, this was the rare case, with less than 2% of the participants having all four of the summation procedures being exactly equal.

An X-Y graph offers a means to visualize the fit of datapoints between two datasets. If equal, all plotted points from the two datasets should lie on the 1-to-1 line. **Figure 8** is a 3-part graphic showing participants' irrigated acre (**Acres$_{CG}$**) correlated against the three other summation techniques. They are: (top) **Acres$_{CG}$** vs **Acres$_{IM}$**, and then (middle) **Acres$_{CG}$** vs **Acres$_{SF}$**, and then finally (bottom) **Acres$_{IM}$** vs **Acres$_{P}$**. The outliers lying outside the 1-to-1 line are datapoints where the datapoint pairs have divergent values and are found in each of the three sub-images.

[12] These same methods that calculate acreage for ALL irrigated crops, can also be employed to specifically enumerate just total rice acres. However, in this case, a fifth avenue would exist to calculate only rice acreage (based on rice watering strategies).

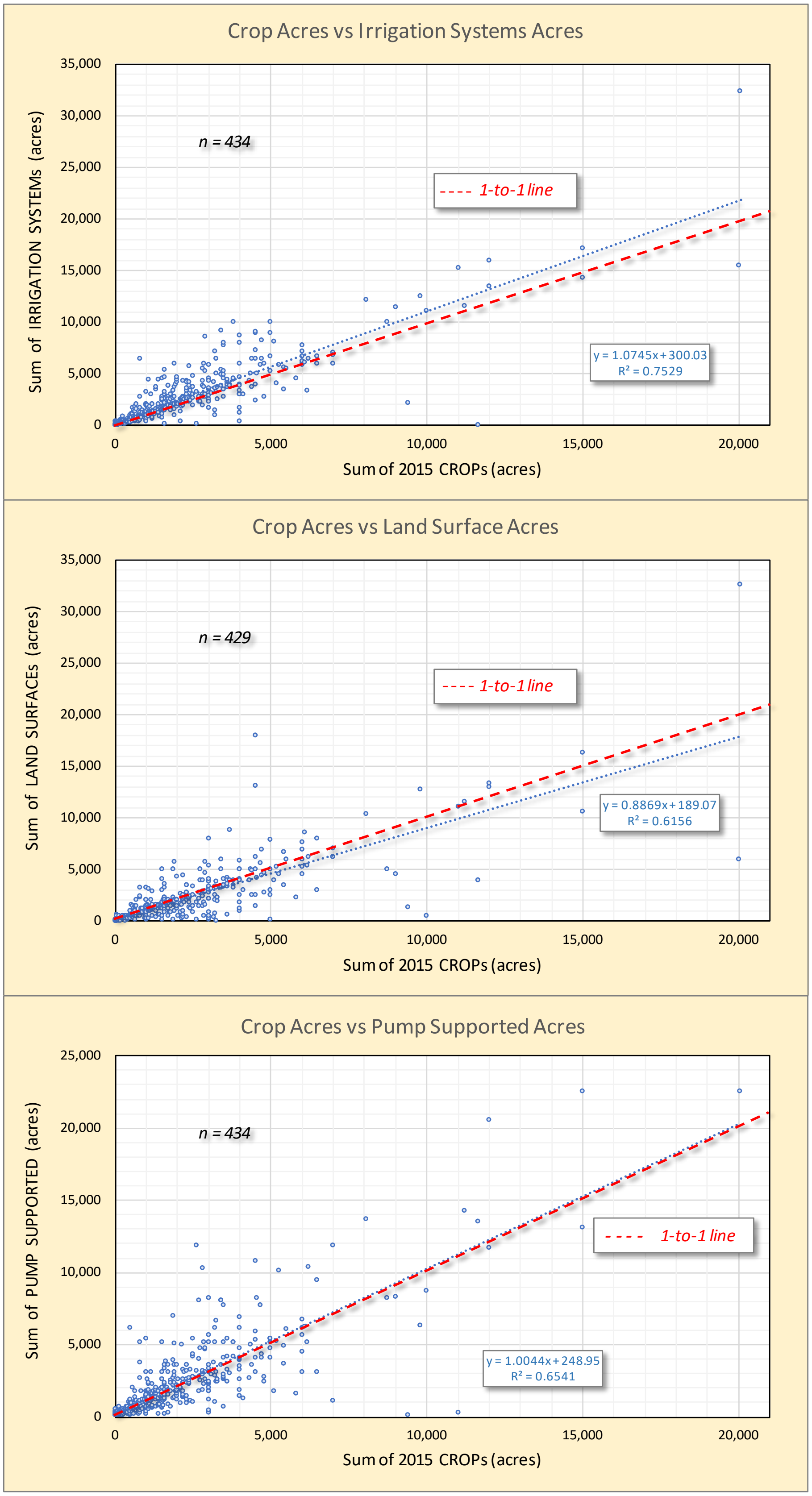


Figure 8. *USBIS* data on 2015 crop acres versus calculated acres based on (top) irrigation systems, (mid) land surfaces, and (bottom) number of irrigation pumps.

As stated, each of the corresponding values from all four of the sets would ideally be exactly equal, but, as mentioned, often does not occur. The percent of variance of those four datapoints can be tested for by dividing their standard deviation by their mean value, as shown in the equation below:

$$\sigma / \overline{x}$$

A resulting value of 0% would indicate that all values were all exactly the same (the desired outcome). The more divergent from each other are the four values, then the result approaches 100%. The average datapoint value was 36.8%. The sample size was based on the number of samples that values for each of the four datasets all were present, which was 405. **Figure 9** shows a histogram of variance values for the 405 datapoints.

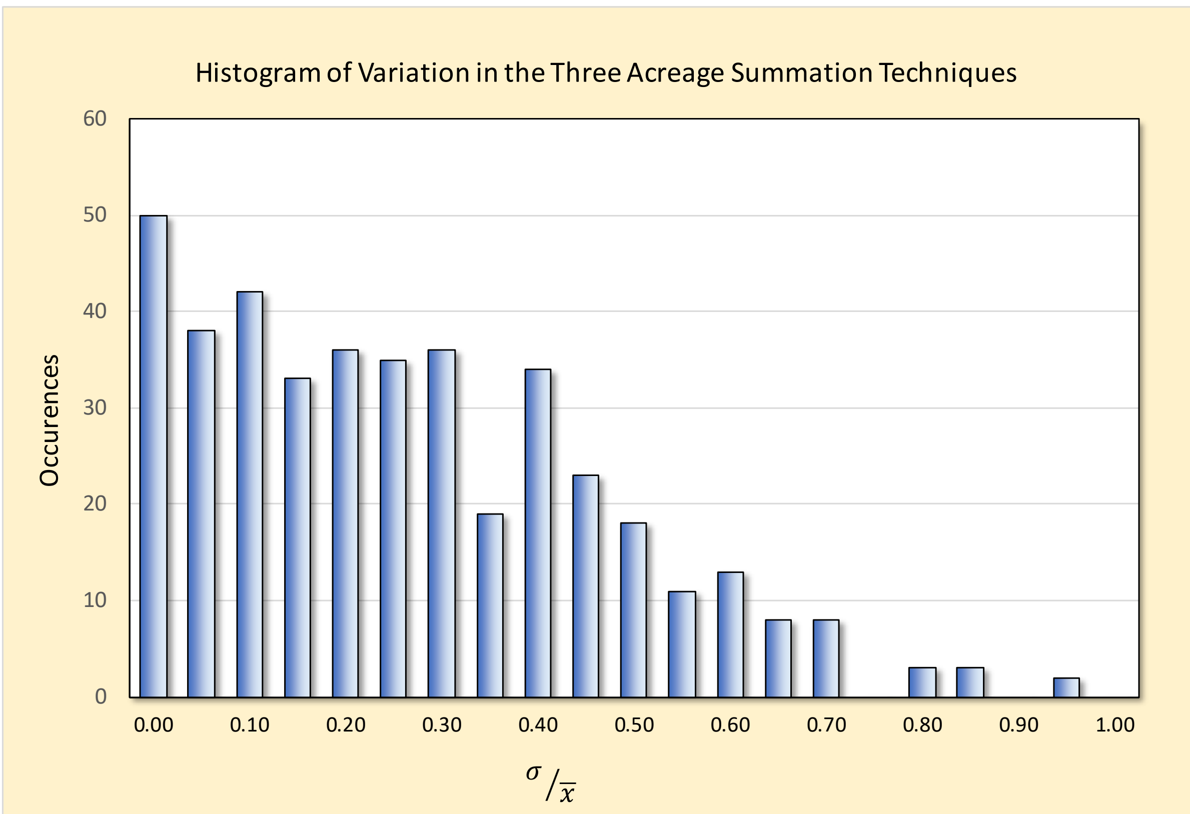


Figure 9. The histogram showing the frequency of occurrences of variance percentages.

5.1 Acreage count based on TYPES of CROPS (*Acres*$_{CP}$)

Only data regarding six major crops of the region was collected: corn, cotton, soybean, rice, peanuts, and grain sorghum. The number of acres for each crop was collected in the ***Q137*** series. However, two other question series referenced each of these crops. One was just a simple Yes/No, asking if they grew that crop (***Q3*** series) and the other asked about expected yield levels for that crop (***Q143***). The latter two mentioned interrogatories provided cross-referencing regarding the quantity of crop acres. If a YES response was given regarding a crop in the ***Q3*** series, then ideally an acreage amount and yield was later supplied in the survey.

- (***Q137***) Please tell me how many IRRIGATED acres you had of each of the following crops in 2015.
- (***Q3***) Do you produce any of the following crops under irrigation?
- (***Q143***) What yield expectation do you have on your farms for the following crops?

The ***Acres***$_{CG}$ levels –being based on just six crops— obviously will be underreported due to the missing irrigated crops. For example, wheat, melons, pumpkins, and sod are all crops that growers had specifically mentioned during the interview process, but for which no planted acreage information was ever collected.

5.2 Acreage count based on IRRIGATION METHODS (*Acres*$_{IM}$)

There seems that there may have been some error involved with the irrigation system method (***Acres***$_{IM}$) of totalizing. In hindsight, during an early stage in the survey coding process, the question about the total number of irrigated acres was omitted in the survey instrument. A question asking for the total irrigated acres would have helped quality check later questions about of their total irrigated acres, how many comprised the different irrigation methods or sub-units. Instead, the participant's total irrigated acreage was collected piecemeal through a series of acreage queries involving **irrigation method subunits** (e.g., center pivots, borders, furrows, etc. – twelve in all [five of which pertained specifically to rice][13]). These subunit values were then summed up, providing the total amount of irrigated acres for each of the interviewees. This type of nested questions was discussed earlier (***3.5 All-inclusive Question Series***).

The irrigation subunits are:

Gravity Irrigation Methods
- Alternate flood & furrow (Q28a)
- Exclusively flood (Q28b)
- Continuously furrow (Q28c)
- Border (Q30)

Pressurized Irrigation Methods
- Drip (Q32)
- Regular center pivot (Q62)
- Towable pivot (Q63)

Rice Irrigation Methods
- Precision grade (Q97_1)
- Contour levee (Q97_2)
- Zero grade (Q97_3)
- Row-water (Q97_4)

[13] The three irrigation subunits are: (***GI***) Gravity Irrigation Methods for all non-rice crops; (***PS***)Pressurized Irrigation Methods for all non-rice crops; and (***RI***) All rice irrigation methods.

Pivot (Q97_5)

The irrigation subunits are seen in **Table 15**. In the lower, center portion of the table is seen the reported acreage amount based on the tally of irrigation methods (**$Acres_{IM}$**); it is derived by summing its component parts (***GI***, ***PS***, and ***RI***). On the table's left wing is shown the 2015 planted crop acreage tally (**$Acres_{CG}$**). Ostensibly, these values will closely match. On the right wing is shown the results of the land surface tally (**$Acres_{SF}$**). Final total acres and the relative ratios to **$Acres_{CG}$** are shown.

Table 15. Factors of crop-related acreage ($Acres_{CG}$) compared to irrigation-related acreage ($Acres_{IM}$) and land surface-related acreage ($Acres_{SF}$)

2015 Crop Planted Acreage (**$Acres_{CG}$**)	Method I: ∑ Irrigation Methods (**$Acres_{IM}$**)					Method II: ∑ of 4 Land surface acres (**$Acres_{SF}$**)
	FIELD CROPS				RICE (RI)	
	(GI) Gravity Irrigation Methods		(PS) Pressurized Irrigation Methods			
∑ of 6 crops	∑ Values from 2 furrow/flood options	Border	Drip	Pivots	∑ Values from 5 rice irrigation methods	
∑ Q137_1 ... Q137_6	∑ Q28b ... Q28c	Q30	Q32	Q62 & Q63	∑ Q97_1 ... Q97_5	∑ Q47_1 ... Q47_4
	739,290 acres	24,627 acres	1,543 acres	169,538 acres		
	763,917 acres		171,081 acres			
	934,998 acres				271,408 acres	
1,024,113 acres (1.000)	1,206,406 acres (1.178)					963,487 acres (0.941)

Figure 10 displays how participant irrigated their crops for the entire mid-South region. The broad-stroked, generalized items (gravity, pressurized, and rice irrigation acres) are displayed in the pie chart. Their contributing portions were 71%, 11%, and 18%, respectively, for gravity, pressurized, and rice irrigation.

The irrigation method having the most acreage was continuously furrow, while the smallest was drip irrigation. The ranking by order of all the various irrigation methods by total area and number is seen in **Table 16**. **Figure 11** shows the amount ([Top] in acres and [Bottom] number of people employing it) of major irrigation methods in the mid-South.

In Q28a, the irrigators were asked of their total irrigated acres, how many alternated between flood and furrow irrigation, when summed, this resulted in 333,357 acres, thus this may explain why the **$Acres_{IM}$** are higher than **$Acres_{SE}$** and **$Acres_{CG}$**. Since these acres can fluctuate between flood and furrow and the acres were in either flood or furrow that year, reducing the total Acres IM by half of the acres that fluctuate between flood and furrow result in 1,039,727 acres very near to **$Acres_{CG}$** and **$Acres_{SE}$**. Thus how the question of irrigated acres and how they are irrigated are a very important detail when conducting an irrigation survey.

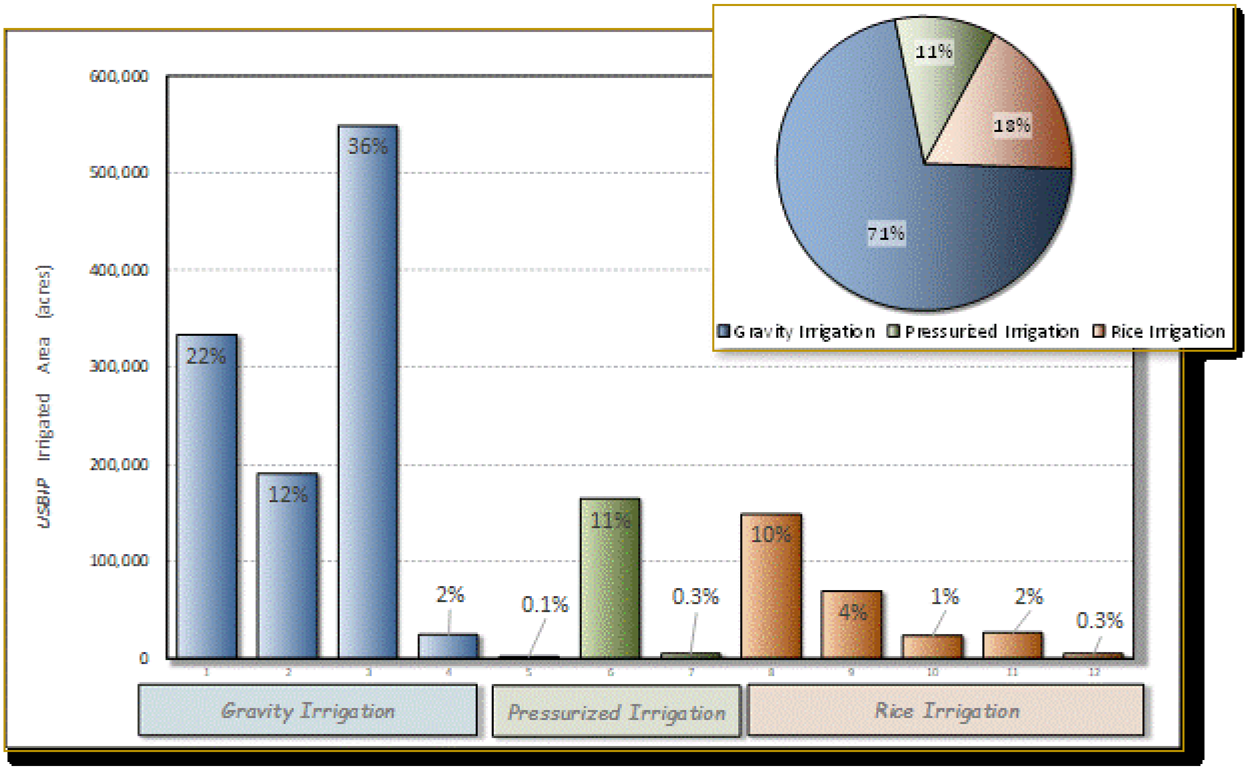


Figure 10. In the *USBIS* irrigated acreage was calculated by summing the components of the three broad categories of gravity, pressurized, and rice irrigation.

Table 16. Ranking of irrigation methods by total area and number

Ranking		Total Area			Number of Users		
		Irrigation Method	(Acres)	(%)	Irrigation Method	(N)	(%)
Smallest ↑	1st	Drip	1,543	0.1%	Drip	9	1%
	2nd	0-grade	22,832	2%	Border	36	3%
	3rd	Border	24,627	2%	0-grade	58	5%
	4th	Contour levee	68,789	6%	Contour levee	106	9%
	5th	Pivot	174,623	15%	Precision grade	163	14%
	6th	Precision grade	148,697	12%	Exclusively flood	194	17%
	7th	Exclusively flood	190,641	16%	Pivot	203	18%
Largest ↓	8th	Continuous furrow	574,654	48%	Continuous furrow	368	32%

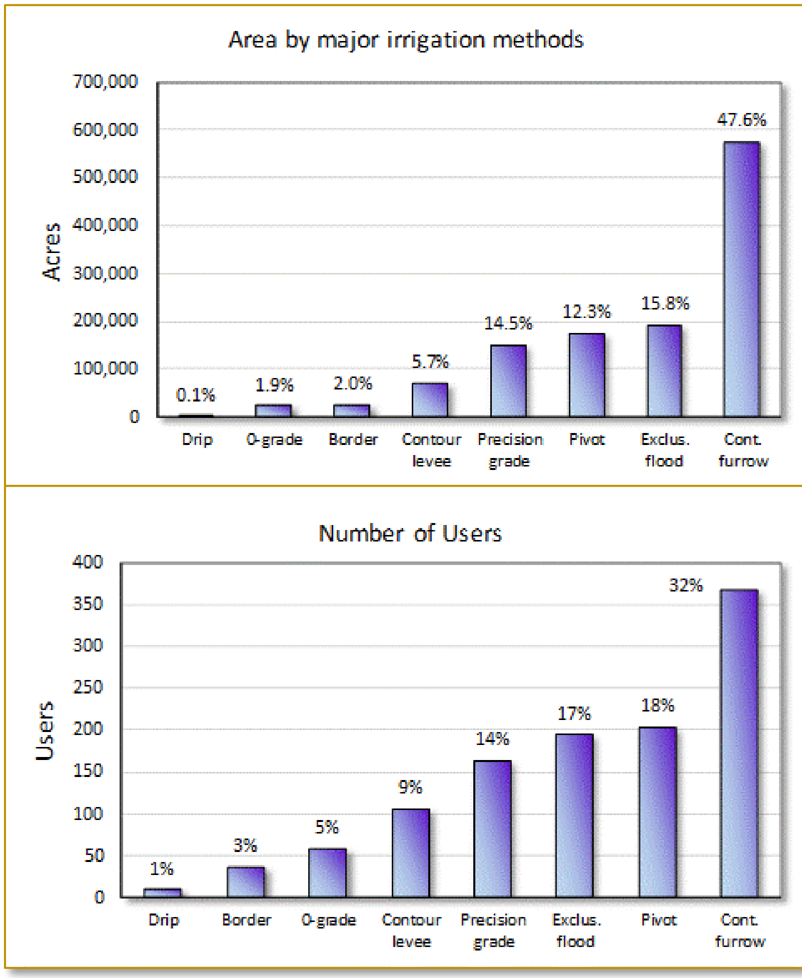


Figure 11. The area (top) and the number of users (bottom) for all major irrigation methods.

5.3 Acreage count based on LAND SURFACE (*Acres*$_{SF}$)

Additionally, an alternative method for deriving irrigated acreage is afforded from the use of the ***Q47*** series of questions (see below), which collected the acreage amount based on surface forming, earlier designated as ***Acres***$_{SF}$. Though this question series appears originally to have been designed to gather insight specifically regarding rice irrigation practices, it also can be employed to calculate the amount of irrigated acreage for all crops. In all, 94.2% of all the 466 interviewees provided information on their farms' land surface (rice growers comprised just a little over 40% of the sample size). Employing this methodology, the 4-state ratio of the sum of ***Acres***$_{IM}$ to the sum of ***Acres***$_{CG}$ (formerly) at 1.50, is now at 0.94 when ***Acres***$_{SF}$ values replace ***Acres***$_{IM}$ values (**Table 15**). The Arkansas ratio between values changed to 0.97 from its previous ratio of 1.76. **Figure 12** shows the individual 2015 crop acres graphed against the individual irrigation method (on top) and the individual surface forming acres (on bottom). The one-to-one line for each graph is shown (also, note that in the case of landform surface acres this one-to-one line lays very close to the graph's linear correlation line).

How many of your TOTAL IRRIGATED acres have been leveled through each of the following means?

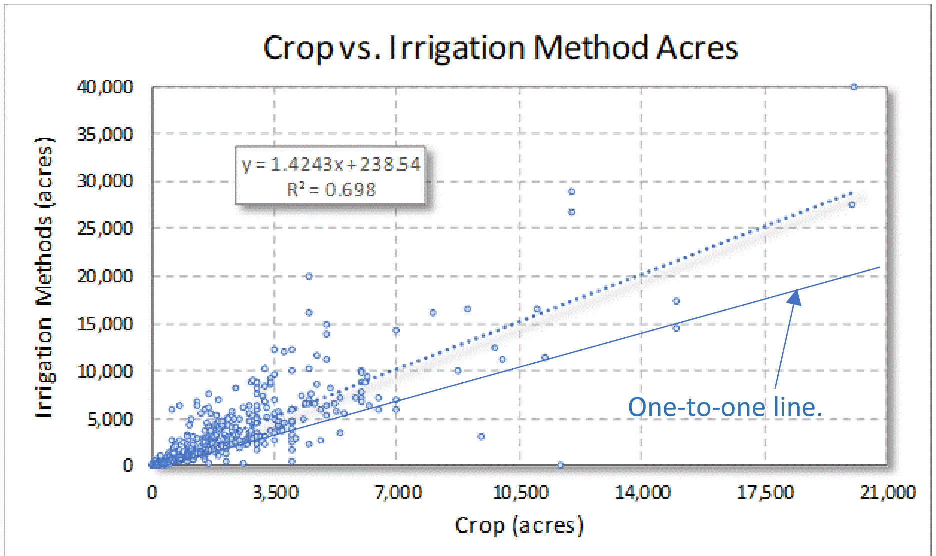
Q47_1 Zero grade ______
- Don't Know (-1)
- Refused (-2)

Q47_2 Precision Grade / Constant Slope ______
- Don't Know (-1)
- Refused (-2)

Q47_3 Warped surface, Opti-Surface (sloped in two directions to minimize earthwork costs) ______
- Don't Know (-1)
- Refused (-2)

Q47_4 Not leveled ______
- Don't Know (-1)
- Refused (-2)

Text Box 4. Survey question series Q47; a secondary means to estimate irrigation acreage



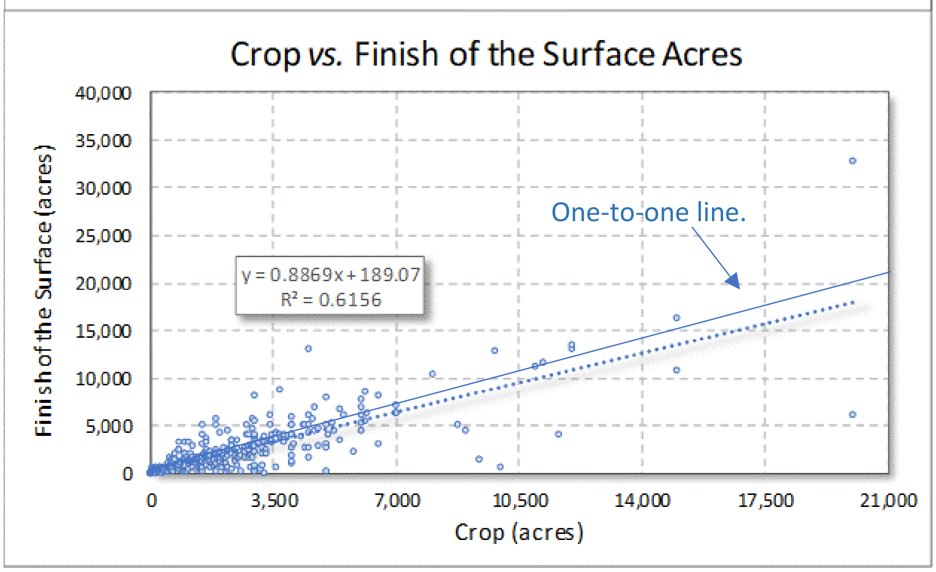


Figure 12. Crop acres compared to irrigation method (top) and surface (bottom) acres.

5.4 Acreage count based on PUMPs (*Acres$_P$*)

A fourth method to estimate participants' irrigated acreage is by using the number of pumps owned by the farmer. Henggeler (1997, etc.) who had annually collected data in irrigation surveys and at conferences (from 1997 to 2010) from framers in the Missouri bootheel and NE Arkansas noted three observations regarding pumps:

- Farmers had a good idea on the number of pumps he owned.
- Farmers were willing to provide this information.
- The value of irrigated acres per pump was relatively constant.

In the USBIS 94.2% of participants reported the number of pumps they had. **Table 17** shows the average number of pumps per participant and the irrigated acres serviced per pump, the latter calculated using ***Acres$_{CP}$*** values. **Figure 13** shows irrigated acres per pump; its R^2 value is 0.75.

Table 17. Number of pumps per farm and irrigated acres served per pump

Region	Pumps / Farm	Acres / Pump
Arkansas	27.2	108.4
Louisiana	9.8	180.4
Mississippi	21.5	185.7
Missouri	28.6	118.3
All 4 States	22.1	147.6

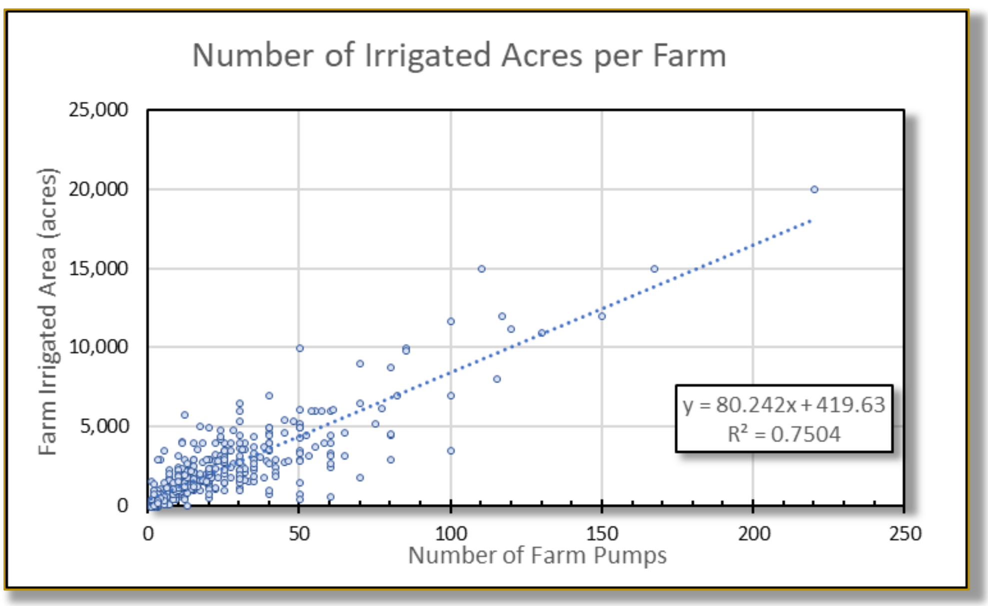


Figure 13. Owner's Irrigated Acres versus the Number of Irrigation Pumps

6 Importance of Survey Data

Baseline Establishment. USDA irrigation analysis shows that over the last two decades the mid-South has greatly increased irrigation. **Figure 4** shows national increases in irrigation over the period 2002 to 2012 (USDA/NASS, 2013). Each blue dot represents an increase of 10,000 acres. The mid-South has the highest density of dots, which have mostly occurred within the confines of the Mississippi River Valley alluvial aquifer.

Concurrently, aquifer levels in parts of the mid-South have steadily declined and severe droughts, once uncommon, appear to be occurring more frequently. During the 2012, this aquifer reached its lowest recorded level in sixty years of monitoring in Missouri (Henggeler, J., 2015).

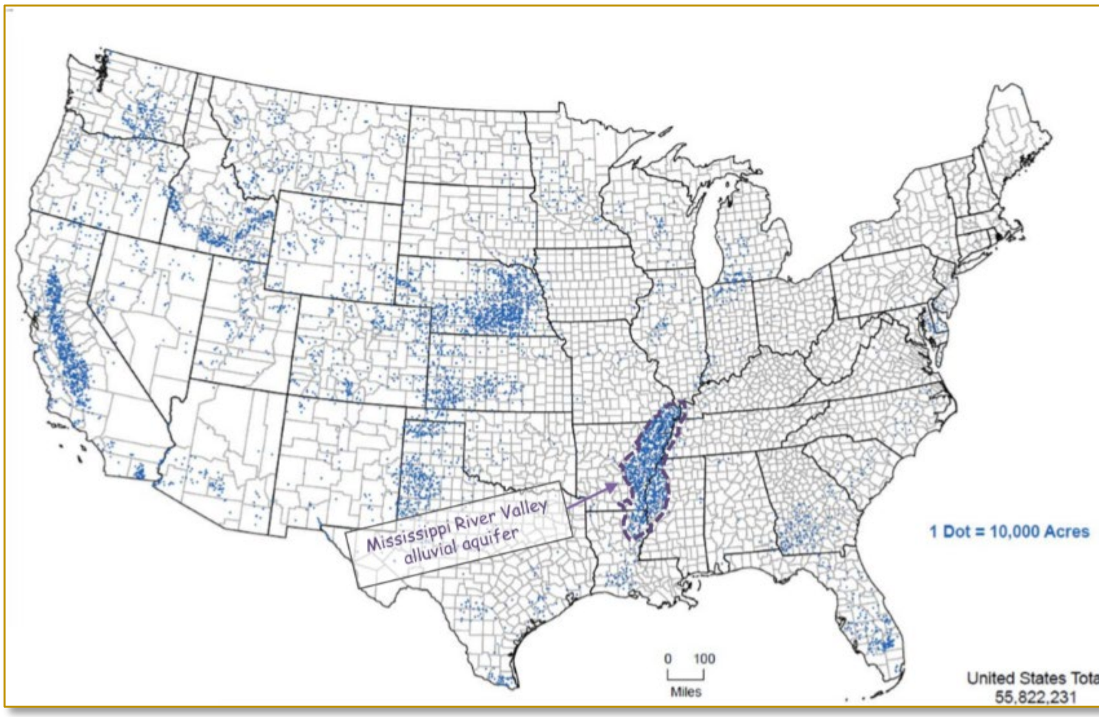


Figure 14. Map showing g

At the same time, some mid-South states have had university irrigation-related resources thinned out. Missouri, a state which had a 40-year-old program (started in 1978) that collected and archived local on-farm irrigation information –a prime source for the mid-South – no longer operates. It is, therefore, very important, under these circumstances, to continue to collect baseline irrigation data for mid-South irrigation conditions.

Baseline data establishes a method for comparisons: changes over time (did a particular program lead to more adoption of an *IBMP*), locale differences, the cross-referencing of information (are yields being affected by the method of irrigation used), and countless other opportunities. The adage, "knowledge is power", certainly applies to the field of irrigation. Having baseline information is the key for making evaluations and comparisons.

Lastly, the current baseline information, when compared to results from future data sets, is how this USB irrigation project can be evaluated.

7 Analyzing Data

Quantifying the Number of Participants. As mentioned often, an important goal of the *USBIP* was to carefully establish baseline data that reflected existing irrigation practices as of 2015. The user participation rate involving (UPR) of various practices was thus compiled to assist in this documentation matter. UPR is the percentage of valid participants indicating they use a practice divided by total number of valid participants. This probably can be viewed easiest by examining a sample drawn from some 80 questions involving a YES/NO response. All of the responses are text values. These questions generally included two to three possible prevaricating responses[14]. Discarding those prevaricating inputs, plus any other input that was null (i.e., a blank), as invalid then leaves just YESs and NOs. The user participation rate is then:

$$UPR = \frac{Yes}{(Yes + No)}$$

The UPR can generally serve as a good metric in using future baseline comparisons, in part due to the fact that participants were forthcoming in supplying their responses. **Table 18** shows the percentages of participant who proffered a valid response on the various question groups. The response rate percentage ($\%_{RR}$) is:

$$\%_{RR} = \frac{(Yes\ + No)}{(TEXT + BLANKs + COUNT)}$$

Where:

TEXT = the number of cells with EXCEL text values.
BLANKs = the number of null value cells.
COUNT = the number of cells with EXCEL numerical values.

The $\%_{RR}$ ranged from 12 to 100%, but was normally very high (>90%) as seen in **Table 18**. The one consistent exception to this involved questions regarding funding methods, where only a quarter of the participants provided a response. Questions regarding pivot irrigation had a mid-range response rate (≈50%). This is most likely due to the fact that pivot irrigation is not the major irrigation method in the mid-South.

So, a caveat is warranted of being careful with UPR results when the $\%_{RR}$ is low.

[14] Prevaricating responses included: “Not Sure”, “Refused”, “Don't Know”, “Prefer not to answer”, and “No furrow irrigation”

Table 18. % of participants who provided either a YES or a NO response.

Item	Number of sub-elements	Participants who responded					
		Arkansas	Mississippi	Missouri	Louisiana	All 4 States	
						4-state mean	Group mean
Plant Crop	8	100.0%	100.0%	100.0%	99.9%	100.0%	95.7%
TWR	1	100.0%	100.0%	100.0%	98.9%	99.8%	
Water	8	98.3%	96.8%	97.6%	96.6%	97.5%	
Ag ed degree?	1	97.0%	95.9%	100.0%	97.8%	97.0%	
Types of Pumps	8	96.9%	98.6%	80.8%	94.4%	96.1%	
Pump Appurtenances	2	96.5%	98.6%	80.8%	94.0%	95.8%	
Conservation Programs	4	95.4%	97.1%	94.2%	95.1%	95.8%	
Irrigation Scheduling	9	99.5%	99.3%	100.0%	71.7%	94.0%	
Method of Irrigation	5	98.9%	99.7%	100.0%	70.9%	93.7%	
CHS	1	99.0%	99.3%	100.0%	70.7%	93.6%	
Farm Practices	2	97.5%	97.0%	88.5%	79.9%	93.3%	
Furrow Management	2	86.3%	90.5%	73.1%	60.9%	81.9%	
Change Pivot Irr Methods	2	66.5%	77.0%	76.9%	46.2%	66.4%	51.3%
Pivot Appurtenances	5	38.0%	58.8%	80.8%	29.3%	45.3%	
Funding Sources	18	32.6%	18.0%	17.1%	18.4%	24.3%	24.3%

The Students' t-test was used to test for a significant difference between the means of two samples. Two sets of independent, non-paired data were tested using the Student t-test. Often times the number of samples in each test were not equal. If differences appear to be present between two groups, does this stem from actual differences in the means, or perhaps from differences resulting from unequal variances. Therefore, before conducting a test on the means, F-tests were performed on the variance of the two samples, determining if equal/unequal variance conditions were in play, and then appropriately determining the degrees of freedom to be used (O'Neal, 2016). Results of the test are provided in the form of:

$$t(DF) = \mathrm{p} > \alpha = 0.05$$

with a comment on significance regarding the t-test and whether conditions of equal/unequal existed provided.

In cases where dependent, paired data existed, the Students t-test of that form was used.

The numeric values derived from the statistical tests are available in Appendix I, *Statistical Results from Survey Questions*, whereas the discussion of the results is presented in the following chapters on: Background of Individuals, Water Resources, Conservation Practices, Energy, Methods of Farming, Methods of Irrigation, and Irrigation Best Management Practices.

A paired samples t-test was used to calculated Pearson Correlation for the acreage amounts found in pairs of these datasets.

Parameter Comparisons. The means from separate groups, such as % ***IBMP*** participation X state or corn yield X by pivot type, were analyzed using the Duncan.

7.1 Validity of Study

7.1.1 Sample Size Validity

This study captured was estimated to capture data representing 1.02 Million irrigated acres of the 13.3 Million acres reported in the region by NASS. The margin of error of this study is 4.6%, 95% CI, 50% Response Distribution based on the number of responses and the estimated number of irrigators in the region.

7.1.2 Initial Observations Regarding Data

A general overview on the types of irrigation methods being used is a good launching point to begin analyzing information provided within this study -- which methods are of the more ubiquitous types, and which one are seldom encountered. For example, the irrigation methods of drip, towable pivots, and pivots on rice collectively represent less than 1% of the irrigated acreage in the mid-South. On the flip side, furrow/flood methods on field crops account for 71% of the total acreage with the subset continuously used furrow accounting for 36% (**Figure 15**).

With this in mind, starting points for understanding deviations from expected outcomes may best be made by reexamining results within the furrow/flood sections of the survey.

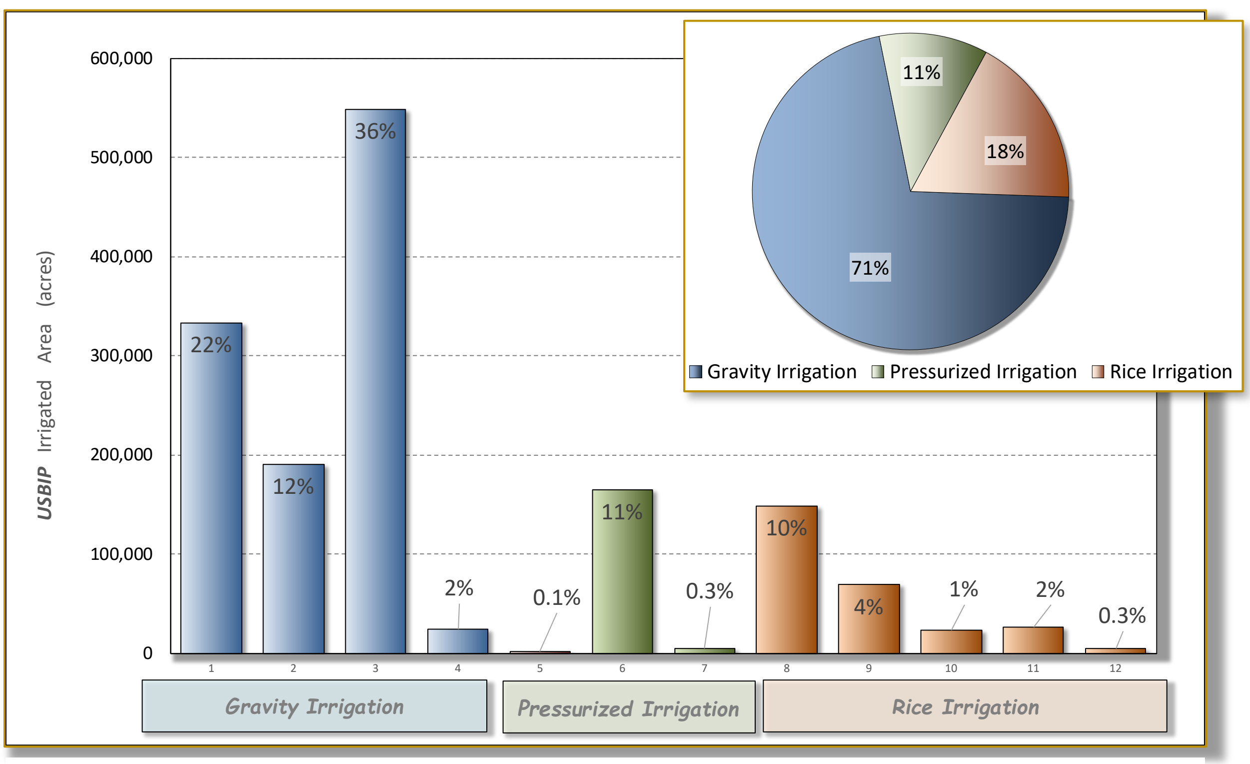


Figure 15. The three broad categories of irrigation in the USBIP report (gravity, pressurizes and rice-related) shown in pie chart with their sub-components illustrated in the bar chart.

7.1.3 Data Validity

Data from the study help define various, current irrigation facts and practices in the mid-South. However, some portions of the study, specifically those involving actual acreage amounts, seemed at odds with itself. In the *USBIP* study, the number of irrigated acres operated by individuals was able to be determined, as previously mentioned, through two separate methods (a crop-based and an irrigation system-based method), which for individuals, frequently differed. This is briefly discussed in the following section (with a more thorough analysis to be found in Appendix II) along with a short presentation on tools for error checking.

As stated, total acreage derived by summing crop acreages (***Acres$_{CG}$***) should be similar in value to the summation values based on methods of irrigation (***Acres$_{IM}$***). But as we point out, were not so. In an earlier report involving just the Arkansas participants (43% of *USBIP* respondents), Northern Economics, Inc (2017) reported:

> *Total irrigated acres by irrigation method is different from total irrigated acres by crop, because figures come from different survey questions. Respondents may irrigate the same acres using multiple methods, use different methods than those asked about in the survey, or give inconsistent figures.*

Their report listed 1,022,056 irrigation system acres for the surveyed farms, but tallied only 600,747 acres of crop, a ratio of 1.70 ***Acres$_{IM}$*** to 1.00 ***Acres$_{CG}$***. The authors reported some possible explanations for the disparity. Other additional reasons, plus further analysis on items, briefly mentioned above, are provided later.

Perfect agreement between ***Acres$_{IM}$*** and ***Acres$_{CG}$*** would result in a 1-to-1 line when the two datasets are plotted together as a graph. **Figure 16** compares all available, complete pairs of ***Acres$_{IM}$* /*Acres$_{CG}$*** values against one another. There are only 438 such pairs, as either crop- or irrigation method-related (or both) acreage tallies are missing for twenty-eight respondents. As can be seen from the outliers, discrepancies existed between the two different acre summation methods. This difference, in cases, was as almost as high as 20,000 acres. Why a survey respondent might over-report or under-report acreage of a crop or acres of irrigation methods being utilized is not known.

The ***Acres$_{IM}$*** and the ***Acres$_{CG}$*** values are shown plotted for the collective three blocks using all data points (**Figure 17**), and then again when outliers are removed (**Figure 18**). Sample size and R^2 values for the set of graphs is shown in **Table 19**. When outliers are removed from determining individual irrigated acreage, then the sample size is reduced 27%. The graphs have the 1-to-1 line illustrated; under perfect agreement all pairs of data points would lie on this line. As illustrated in **Figure 16**, the disparity between ***Acres$_{IM}$*** and ***Acres$_{CG}$*** values was as extreme as a low of -18,420 to a high of 11,646 (calculated as ***Acres$_{CG}$*** - ***Acres$_{IM}$***). In the latter mentioned discrepancy example, the respondent reported <u>0 irrigation method acres</u>, but on the other hand reported 11,646 acres of irrigated 2015 crops.

Outlier values were determined by limits on both acceptable ratios AND acceptable differences involving ***Acres$_{IM}$*** and ***Acres$_{CG}$*** values. Data pairs were considered outliers when both following conditions were met:

$$\left[\frac{Acres_{IM}}{Acres_{CG}}\right] \; or \; \left[\frac{Acres_{CG}}{Acres_{IM}}\right] \geq 2.0$$

+

$$abs(Acres_{IM} - Acres_{CG}) \geq 200$$

Table 19. Sample size, R^2 and % of original n for demarcation blocks with and without outliers.

Block	All Data		Outliers Removed		
	n	R^2	n	R^2	% of original sample
Rice	195	.497	150	.862	76.9 %
Non-Rice Field Crops	406	.597	281	.918	69.2 %
All Rice and Non-Rice Field Crops	438	.711	320	.900	73.1 %

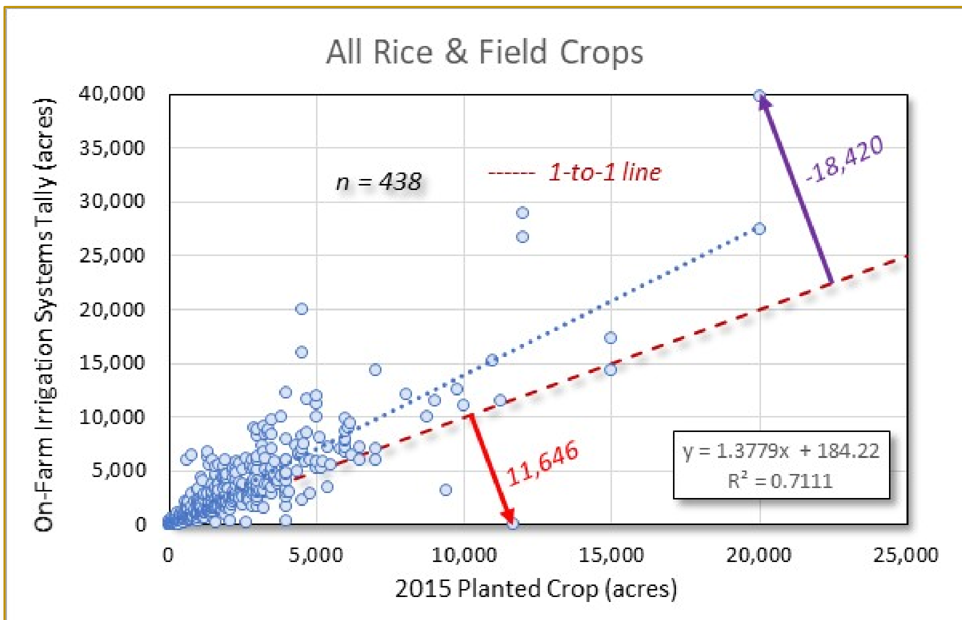


Figure 16. Farm irrigated acreage as determined using two methods, showing 1-to-1 line and absolute discrepancy above and below this line.

Comparing just the "Rice" and the "All Crops, but Rice" blocks, one finds the p values for two-tailed comparisons are smaller for the field crops group then for the rice group, both with and without outliers (**Table 20**), which speaks to the fact that the means for the crop- and irrigation-based acreages of the "Rice only" block corresponded closer with one another. Recall that the two sample means that are being tested for are irrigated acreages as calculated by the crop method (***Acres****CG*) and that calculated by the irrigation method (***Acres****IM*). As intimated earlier, questions regarding farmers' various methods used in the irrigation of rice were clearer than those questions asked about methods used in irrigating non-rice field crops. **Table 21** contains full information on the Student T-Tests performed on all three demarcation blocks both with outliers included and excluded.

Table 20. The p-values for mean acreages of rice versus field crops with and without outliers

Data Used	Block	p
All data points	Rice only	0.018448
	All field crops, but rice	0.000002
Outliers removed	Rice only	0.613646
	All field crops, but rice	0.103968

Table 21. Statistical information between ALL and OUTLIER-REMOVED acreages using crop- versus irrigation-method summations of farm irrigated acres for rice, all field crops but rice, and all crops.

Sub Group	What Tested	Mean 1	Mean 2	Df (t-Test)	t-Test (T_{STAT})	T_{CRIT} - two-tail	Prob Equation	Significance ?	p (T<=t) two-tail	Variance
Rice	All	1,030	1,381	302	-2.369	1.980	t (302) = -2.369 p > 0.05	Significant difference, 0.05 level	0.018448	Unequal
	No Outliers	985	1,042	298	-0.505	1.980	t (298) = -.505 p > 0.05	N. S.	0.613646	Equal
ALL Crops but Rice	All	1,953	2,916	695	-4.786	1.980	t (695) = -4.786 p > 0.05	Significant difference, 0.05 level	0.000002	Unequal
	No Outliers	2,099	2,475	529	-1.629	1.980	t (529) = -1.629 p > 0.05	N. S.	0.103968	Unequal
ALL Crops	All	2,289	3,339	724	-4.555	1.980	t (724) = -4.555 p > 0.05	Significant difference, 0.05 level	0.000006	Unequal
	No Outliers	2,331	2,816	574	-1.903	1.980	t (574) = -1.903 p > 0.05	N. S.	0.057499	Unequal

A view of the state-by-state acreage amount comparison calculated by crop- versus the irrigation method- tallies (with outliers removed outliers) can be seen in **Figure 19**.

Approximately 30% of the *USBIP* survey responses had $\boldsymbol{Acres_{IM}}$ and $\boldsymbol{Acres_{CG}}$ values that were inconsistent with one another, posing the questions: Which of the two is the correct value? Or, is either one even the correct value? However, on the positive side, 70% of the sample had similarity between the two separate, different tallying methodologies (i.e., $\boldsymbol{Acres_{IM}}$ and $\boldsymbol{Acres_{CG}}$) used to establish a respondent's acreage, thereby corroborating this value.

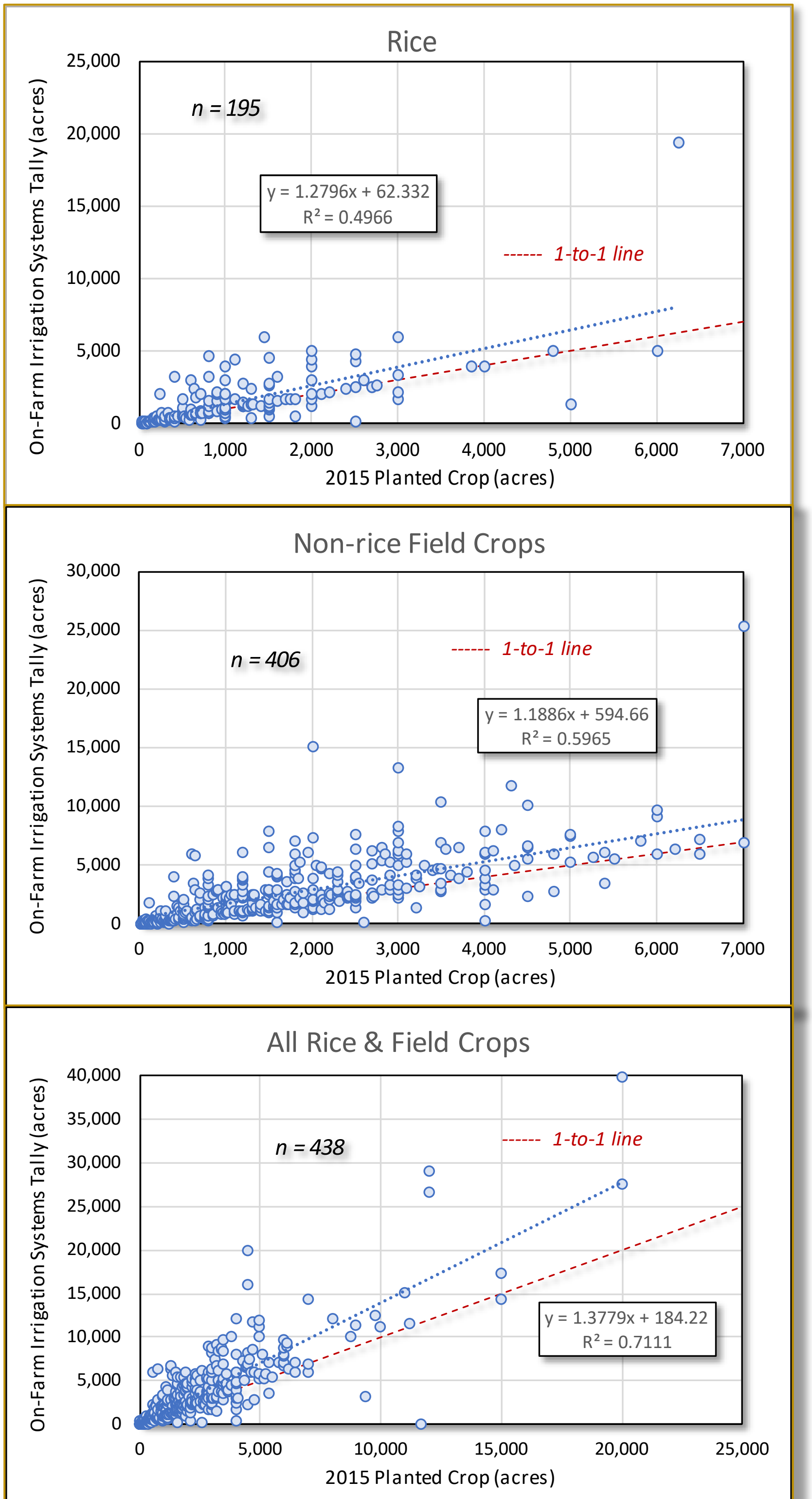


Figure 17. Comparing acreage amounts derived using $Acres_{IM}$ versus $Acres_{CG}$ using all values: (top) Rice, (mid) all non-Rice crops, and (bottom) all rice & non-Rice crops

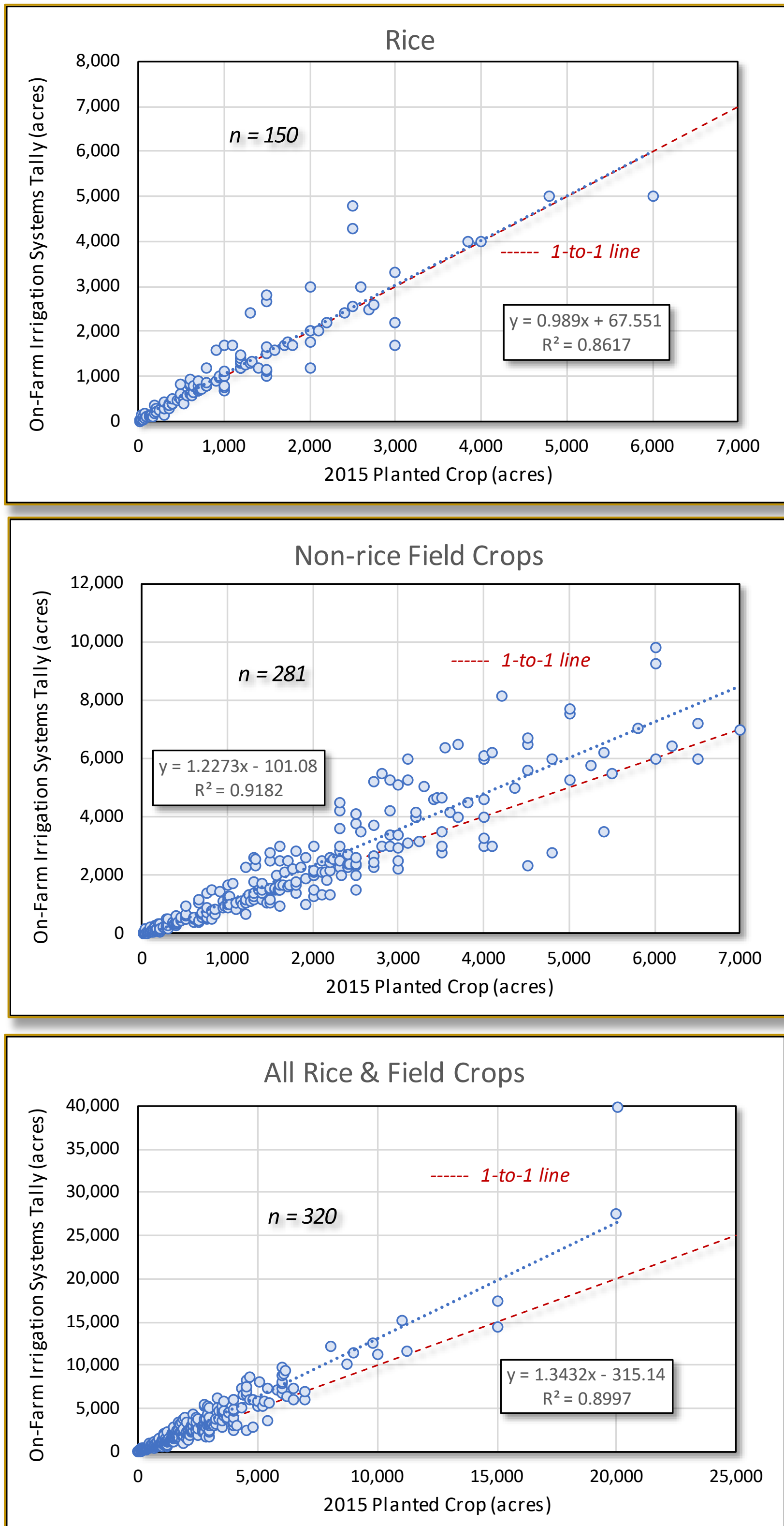


Figure 18. Comparing acreage amounts derived using ***Acres$_{IM}$*** versus ***Acres$_{CG}$*** with <u>outliers removed</u>: (top) Rice, (mid) all non-Rice crops, and (bottom) all rice & non-Rice crops

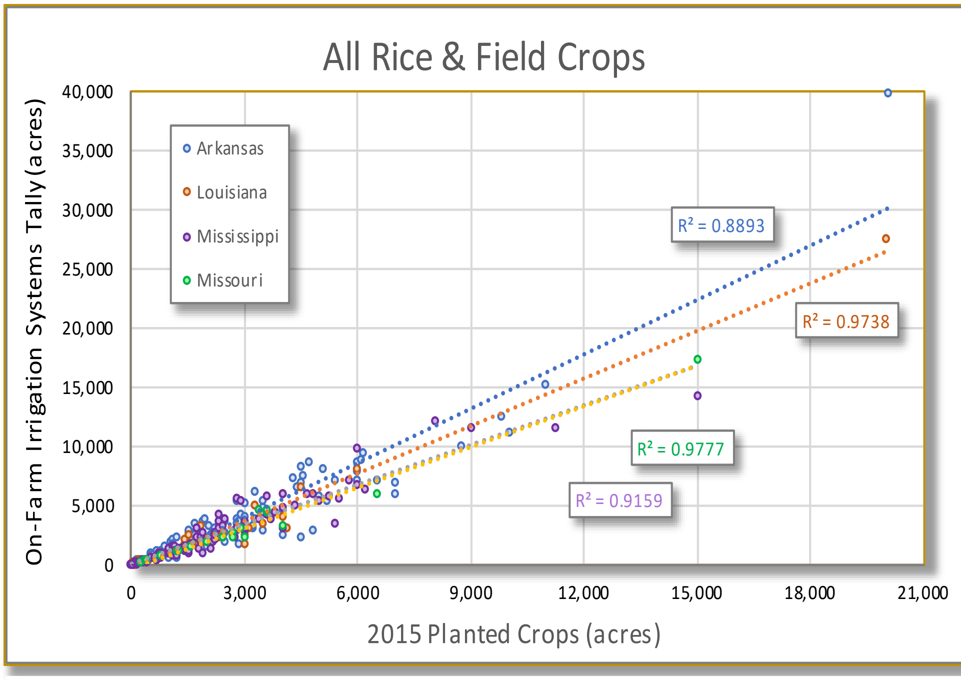


Figure 19. State-by-state comparison of acreage amounts calculated by crop- versus irrigation method-tallies with outliers removed.

8 Background of Individuals

8.1 Residency

Respondents came from 101 different counties/parishes in the mid-South; Arkansas and Mississippi with 33 each (albeit Arkansas's 33rd one is "Refused"), Louisiana with 27, and Missouri with 8. **Table 22** lists these counties/parishes; also, the number of participants from each county/parish can be seen in parenthesis.

Table 22. The survey states, their counties & number of participants

Arkansas		Louisiana		Mississippi		Missouri
Arkansas (19)	Lawrence (5)	Acadia (7)	Madison (6)	Adams (2)	Newton (1)	Butler (1)
Ashley (4)	Lee (9)	Allen (2)	Morehouse (11)	Bolivar (15)	Noxubee (2)	Cape Girardeau (2)
Chicot (9)	Lincoln (2)	Beauregard (3)	Ouachita (2)	Chickasaw (1)	Panola (5)	Dunklin (2)
Clay (6)	Lonoke (7)	Bossier (4)	Natchitoches (3)	Coahoma (21)	Quitman (5)	Mississippi (4)
Conway (3)	Mississippi (8)	Caddo (5)	Pointe Coupee (1)	DeSoto (1)	Rankin (1)	New Madrid (7)
Craighead (18)	Phillips (8)	Calcasieu (1)	Rapides (1)	George (1)	Sharkey (2)	Pemiscot (2)
Crittenden (11)	Poinsett (10)	Caldwell (2)	Red River (1)	Hinds (1)	Tallahatchie (5)	Scott (2)
Cross (13)	Pope (1)	Concordia (1)	Richland (4)	Holmes (5)	Smith (1)	Stoddard (6)
Desha (8)	Prairie (8)	East Carroll (7)	Saint Charles (1)	Humphreys (4)	Tate (2)	
Drew (3)	Pulaski (3)	Evangeline (3)	Saint Landry (3)	Lafayette (1)	Union (1)	
Faulkner (3)	Randolph (6)	Franklin (5)	Vermilion (2)	Lee (1)	Sunflower (19)	
Greene (4)	St. Francis (2)	Iberville (1)	West Carroll (1)	Leflore (17)	Tunica (8)	
Independence (1)	White (4)	Jefferson Davis (9)	Tensas (3)	Lincoln (1)	Warren (2)	
Jackson (7)	Washington (2)	Lafayette (4)		Lowndes (1)	Washington (10)	
Jefferson (3)	Woodruff (5)			Madison (1)	Yalobusha (2)	
Lafayette (5)	Yell (1)			Monroe (1)	Yazoo (7)	
Refused (1)				Montgomery (1)		

8.2 Land Ownership

The irrigation stakeholders that were queried needed to be actively involved in the actual operation of irrigation in order to provide data for the survey. Thus, those participants must have described themselves in question ***Q2*** in either one of two ways: as either "Operator only" or as "Landowner and operator." Data were not collected from non-active landowners ("Landowner only" category [18% of the contacted group originally agreeing to be interviewed]).

Q2

Would you consider yourself a...

- ʘ Land owner only (1) [END SURVEY]
- ʘ Operator only (2)
- ʘ Land owner and operator (3)
- ʘ Prefer not to respond (4) [END SURVEY]

Text Box 2. Survey question Q2 re: land ownership and whether operates the farm

The “operator only” category, in effect, are farmers who would normally be termed “renters”. Within the survey, those who provided irrigation information were broadly categorized as to being either “owners” or “renters” (**Table 23**), thus presenting a black or white demarcation regarding ownership. However, there would probably be some grey area, where many of the survey participants may have owned some portions, while, at the same time, renting other portions of land they were irrigating. However, the actual breakdown between what percentage of irrigated land was outrightly owned versus what might be rented fell beyond the scope of the survey.

It is assumed that “operator only” farmers (approximately 20% of the responding group) rented in totality the land they were irrigating, not owning any of it. This ratio of renter: landowner remained consistent between all four participating states. It might reasonably be expected that the aspect of ownership would have bearings on irrigation survey results, such as (1) farm size and (2) farm management approaches (e.g., renters being less likely to be involved with irrigation enterprises involving large capital investments, such as pivots, drip irrigation, and land leveling). **Table 23** shows the state-by-state breakdown of people contacted in the survey whose input was utilized (i.e., [1] landowner & operators and [2] operator only), plus the group contacted, for which no data was collected from them (i.e., landowner only).

A point of interest, not part of the survey data set, is the amount of dryland acres that might have been farmed by the participants in each state. **Table 24** shows the amounts of irrigated and dryland acres in each state based on USDA records. On average for all four states, the respondents were likely to be farming half again as much land in dryland enterprises, as in their reported irrigated farms. The amount of additionally farmed dryland ranged from a low of 19% for Arkansas to a high of 55% for southeast Missouri.

Regarding the question of whether owners and renters farmed equivalent amounts of land, in most states they did; overall, the owner-to-renter ratio was 0.95. Louisiana had the smallest ratio (0.57), and Mississippi was the only state where renter acreage was larger than owner acreage (its ratio was 1.32).

Table 23. Size of samples and % for type of ownership stake

Location	Data was collected					No data was collected	
	Landowner and operator	%	Operator only (renter)	%	Total Sample Size	Landowner only	% of contacted sample who were “Landowner only”
Col. (A)	Col. (B)		Col. (C)		Col. (D)	Col. (E)	Col. (F)
Arkansas	161	81%	37	19%	198	375	47.2%
Louisiana	70	80%	18	20%	88	408	78.4%
Mississippi	113	79%	30	21%	143	423	66.2%
Missouri	20	83%	4	17%	24	72	66.7%
All 4 States	364	80%	89	20%	453	1278	64.6%

Table 24. Irrigated and dryland acreage in the region as reported by USDA

Location	Irrigated Acres	%	Dryland Acres	%
Arkansas [A]	4,950,053	81%	1,192,818	19%
Louisiana [A]	1,096,381	49%	1,119,603	51%
Mississippi [A]	1,701,587	61%	1,066,507	39%
Missouri [B]	977,816	45%	1,188,156	55%
All 4 States	8,725,837	66%	4,567,084	34%

[A] 2012 Census of Agriculture, 8 2013 FRIS - Entire Farm Data, Table 3.
[B] 2012 Census of Agriculture, MO: 544 Missouri - County Data, Table 24.

The Students' t test was used to test for a significant difference ($\alpha = 0.05$) between the means of the two sets (owner or renter) for the variables evaluated. Sample values were unpaired (independent), and an F-test, determining if variance was equal or unequal was first done, before determining the degrees of freedom to use with the t-test (O'Neal, 2016).

Whether one is an owner or renter appears to have little bearing regarding significance between variables in most cases, such as crop yields, acres irrigated, etc. However, in other instances it does; for example, owners have about ten more years of experience farming then do renters. Additionally, owners are about a quarter more likely to be involved in government assistance programs, like EQIP, etc. then are renters. (Note: Any existing owner/renter trends that are significant will be mentioned in the appropriate section). The mean differences between the two groups were the greatest regarding government programs and certain background aspects (e.g., household income, years farming, etc.). **Table 25** lists these variables with the greatest discrepancy ($\alpha = 0.05$) in means between owner and renter, as determined with the Student t-test. Note that a positive value for ***p*** in **Table 25** and **Table 26**, signify the landowner is dominant, while a negative value for ***p*** signifies renter dominance.

Table 26 list variables with smaller amounts of discrepancy between means ($\alpha = 0.20$) and though they wouldn't be referred to as being significant, that might infer a trending relationship. This group of variables include several ***IBMP***s that renters appear more likely to be implementing. As before, the T_{STAT} value is negative when the renters' mean >the owners' mean.

Table 25. Student t-test results for mean values of owners (x) and renter (y), $\alpha = 0.05$ level

Variable	Mean $_X$	Mean $_Y$	n $_X$	n $_Y$	DF	t-Test (T_{STAT})	T $_{CRIT}$	Prob. Equation	Significance	p (T<=t)	Variance
Yrs. farming	33.5	23.0	371	93	462	6.321	1.980	t (462) = 6.32 p > 0.05	S. D. $_{0.05 \text{ level}}$	0.0000	Equal
Household $	$168,283	$124,924	258	66	121	2.483	1.980	t (121) = 2.483 p >0.05	S. D. $_{0.05 \text{ level}}$	0.0144	Unequal
# of timers	14.6	8.0	92	19	106	2.440	1.984	t (106) = 2.439 p >0.05	S. D. $_{0.05 \text{ level}}$	0.0164	Unequal
% in EQIP	58%	45%	358	93	449	2.294	1.980	t (449) = 2.294 p >0.05	S. D. $_{0.05 \text{ level}}$	0.0222	Equal
∑ govt programs	1.39	1.14	373	93	464	2.013	1.980	t (464) = 2.014 p > .05	S. D. $_{0.05 \text{ level}}$	0.0446	Equal

[A] Two-tail t-test.

Table 26. Student t-test results for mean values of owners (x) and renter (y), α = 0.20 level

Variable	Mean $_X$	Mean $_Y$	n $_X$	n $_Y$	DF	t-Test (T_{STAT})	T_{CRIT}	Prob. Equation	Significance	p (T<=t)	Var.
Surge	9.0	15.5	57	17	72	-1.8473	2.000	t (72) = -1.847 p >0.05	N. S.	0.0688	Equal
SMSs	22%	31%	350	88	436	-1.775	1.980	t (436) = -1.775 p > 0.05	N. S.	0.0765	Equal
Use propane	12%	7%	358	90	174	1.777	1.980	t (174) = 1.777 p > 0.05	N. S.	0.0772	Equal
CRP	0.44	0.34	363	91	452	1.732	1.980	t (452) = 1.732 p > 0.05	N. S.	0.0840	Equal
# sched methods	1.5	1.7	373	93	464	-1.651	1.980	t (464) = -1.651 p > 0.05	N. S.	0.0994	Equal
Routine sched	26%	34%	350	88	436	-1.460	1.980	t (436) = -1.46 p > 0.05	N. S.	0.1449	Equal
Use groundwater	86.8	82.7	342	87	117	1.391	1.984	t (117) = 1.391 p >0.05	N. S.	0.1670	Equal
# perm. meters	7.0	5.4	144	35	111	1.384	1.984	t (111) = 1.384 p > 0.05	N. S.	0.1691	Equal
CHS	40%	47%	349	87	434	-1.286	1.980	t (434) = -1.286 p > 0.05	N. S.	0.1991	Equal

[A] Two-tail t-test.

8.3 Years of Farming Experience

On Question ***Q136***, the survey participants were asked about the number of years of farming experience they had. Note that it is not the years of irrigation experience they had.

How many years of farming experience do you have?

Q136 ______
Don't know (1)
Refused (2)

Text Box 3. Survey question Q136 re: years of farming experience

The average number of years of farming experience for the mid-South was 31.4 years. Mississippi irrigators had the least with 28.2 years, while Missouri's 35.6 years of experience was the highest. Land ownership status exhibited a discrepancy with owners having over ten years more farming experience then did the renters (**Table 27**). **Figure 20** is a frequency histogram showing the number of sample size in 10-year increments from 0 – 10 to 70-80.

Table 27. Years of farming experience for owners & renters by state, sample size shown as (n)

Location	Owners	Renters
Arkansas	35.2 (n = 161)	22.3 (n = 37)
Louisiana	33.8 (n = 72)	27.7 (n = 21)
Mississippi	30.4 (n = 116)	20.2 (n = 31)
Missouri	37.2 (n = 22)	27.0 (n = 4)
All 4 States	33.5 (n = 371)	23.0 (n = 93)

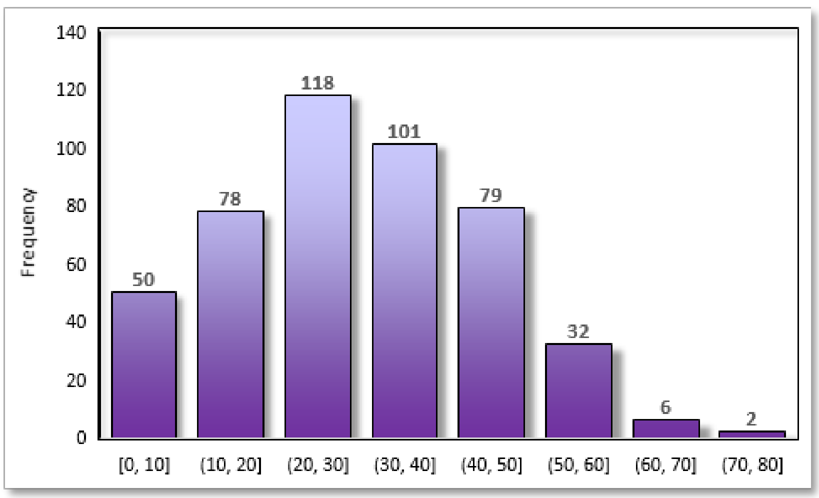


Figure 20. Histogram showing participants' years of farming experience

8.4 Educational Background

Information regarding a participant's level of education was asked about in two ways: first, the amount of formal education (ranging within seven categories starting at "no formal education" to "beyond master's degree) the participant might have attained was asked (**Table 28**). This tabulation is basically in ascending order of time in school; **Table 29** represents an attempt at quantification using the aforementioned table. Additionally, the participants were asked if any of the degrees that the participant had obtained were related to agriculture,

The average score level for the 466 participants was 4.98, roughly equivalent to "Completed Associate degree (2-year program)." The scores between states were very similar (+ or – 0.12) and are seen in **Table 29**. Approximately, one half of the group had an agricultural degree ( ). Missouri had the highest rate with 69% and Mississippi the lowest with 44%.

Table 28. Scale used to quantify educational level

Rating	Level of Education
1	No formal education
2	Less than high school
3	Completed High School or GED equivalent
4	Some college or vocational program
5	Completed Associate degree (2-year program)
6	Completed Bachelor's **degree** (4-year program)
7	Completed Master's degree
8	Beyond Master's degree

Table 29. Mean educational level scores by state based on values from Table 28

Location	Mean Education Level	n	Variance
Arkansas	4.91	199	2.402
Louisiana	4.94	93	2.278
Mississippi	5.07	147	1.960
Missouri	5.15	26	2.535
All 4 States	4.98	465	2.237

Table 30. Percentage of participants with agriculture degrees

Location	% with ag degree	n	Variance
Arkansas	56%	193	24.7%
Louisiana	48%	91	25.3%
Mississippi	44%	142	24.9%
Missouri	69%	26	22.2%
All 4 States	52%	452	2.5.0%

8.5 Household Income

In the survey both irrigation-related and demographic data was collected. Demographic data included location (i.e., state and county/parish) and socio-economic information, specifically, the stake-holder's household income. **Table 31** are the income level bins used; there were 13, ranging from < $10,000 to > $300,000.

Table 31. Household income scale

Rating	Income Level
1	Less than $10,000
2	$10,000 to $15,000
3	$15,000 to $20,000
4	$20,000 to $25,000
5	$25,000 to $35,000
6	$35,000 to $50,000
7	$50,000 to $75,000
8	$75,000 to $100,000
9	$100,000 to $150,000
10	$150,000 to $200,000
11	$200,000 to $250,000
12	$250,000 to $300,000
13	More than $300,000

Table 32. Mean household income level by state based on values from Table 31

Location	Mean Household Income Rating	n	Variance
Arkansas	8.55	154	6.197
Louisiana	9.51	57	6.647
Mississippi	8.68	101	5.419
Missouri	8.75	12	8.023
All 4 States	8.77	324	6.160

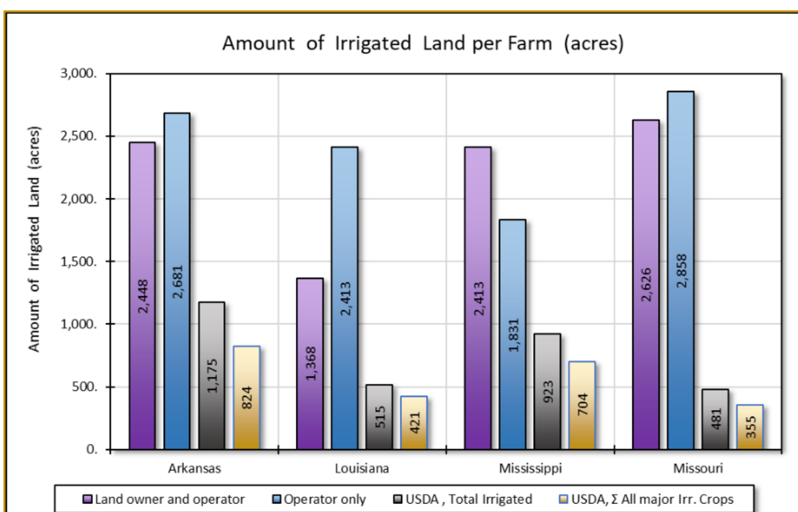
Table 33. Estimated mean household income by state based on values from Table 31 & Table 32

Location	Mean Household Income Rating	n
Arkansas	$148,289	154
Louisiana	$207,061	57
Mississippi	$148,371	101
Missouri	$169,792	12
All 4 States	$159,451	324

The survey results based on the household income score are found in **Table 32**. Tabulation shows a mean value for all participants to be 8.77, with Louisiana above the 4-state mean, while the other three states lie below this regionwide mean. An estimate, in terms of dollars, can be had by multiplying the frequency amount of each bin times the average of the high and low limits of that bin. Bins #1 and #13, lying on either ends of the set of bins, can introduce some error in the calculated, state average household income for irrigators in the states using the mentioned algorithm. The Bin #1 error would only be small, since the dollar amount is itself small, in addition, only 1% irrigators, of the 324 who provided information on this question, fit in that category. On the other hand, the particulars of Bin #13 are just the opposite of those of the Bin #1 case. First, a sizable number, 42 respondents (13% of the sample), fell into this category. Secondly, it remains unknown just how far beyond the $300,000 delimitation of this category, a grower's net household income lies. The value of $400,000 was used in tabulating **Table 33**.

8.6 Size of Farm

Over all, the average amount of irrigated land per respondent was large. It was either 2,259 acres based on ***Acres***$_{CG}$ acreage amounts (1,023,313 acres / 453 respondents), or 3,302 based on ***Acres***$_{IM}$ acreage amounts (1,469,434 acres / 445 respondents). Using the former, the minimum reported farm size was 5 acres, while the maximum was 20,050 acres. Data on average irrigated holdings in acres for both owners and renters for each state is shown in **Figure 21**. Note that these values are disparagingly different from that reported in the USDA Farm and Irrigation Survey, 2012. The reason that this may be happening is that the USDA data collected is based on Farm Service Agency (FSA) information, and it is known that some growers have multiple FSA farm numbers. The fourth column in **Figure 21** (it is also USDA data), is based on irrigated acreage values being calculated by summing the acreage amounts for the six main irrigated crops in the survey. Thus, someone growing, say, corn, soybeans and rice, is tabulated three time as an irrigation user. While the accuracy for the summation method regarding <u>total irrigated</u> acres should be fine, the value for <u>average irrigated acreage per farmer</u> becomes skewed (and always will decrease in size) as head count increases with the number of FSA crops reported on.[15]



[15] *Nota bene*: Commenting here regarding the use of a summation of crops approach, which we have shown will give false, inflated number of irrigators, is presented here as a caveat for people on the errors that would accrue in the actual number of irrigators, which then (because the acreage amounts are correct), leads to estimates of farm size being too small (which initially this author had done).

Figure 21. Irrigated acres per respondent based on ownership (owning or renting) by state. Also shown are USDA (2012) values for average irrigated farm acreage calculated by two methods: Total farm irrigated area (Table 2) and Σ of all major irrigated crops (Table 24)

Individual farms from the four states were grouped by size into four groups. The ***Q137*** series of questions that asked about 2015 planting intentions for six different irrigated crops was used to ascertain total irrigated farm size after summing the values from each of the six crops. Farm size then was correlated to various parameters and examined. Individual mean values for each of the state's four size-grouped samples was calculated by averaging all values that fell within those bin groups. These farm size data were then correlated to various parameters collected in the survey.

One comparison that stood out among the various correlations examined would appear to be counterintuitive; as the years of farming experience (we are assuming it would reflect the age of the farmer) decreases, so does farm size as seen in **Figure 22**. Tables from the Northern Economics study (2017) indicate similar trending with their largest ownership groups (3,200+ acres) having 9 years less experience then the three other smaller ownership groups.

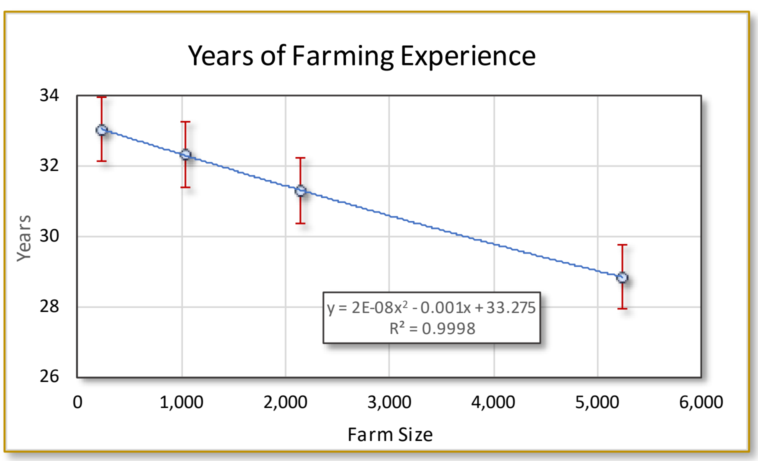


Figure 22. Relationship of years of farming experience and size of farm

The distribution of the number of acres farmed by participants for the six various irrigated crops showed a surprising amount of top-end disparity. For example, 10% of the largest corn irrigators controlled a full 40% of the irrigated corn acreage (Figure 23**). In the case of soybeans, this trend is even more pounced with 10% of irrigators representing almost half the acres.**

Table 34 lists percentage of irrigated acreage under control of the top 10% and 20% of irrigated landowners for corn, cotton, soybeans and rice for each state.

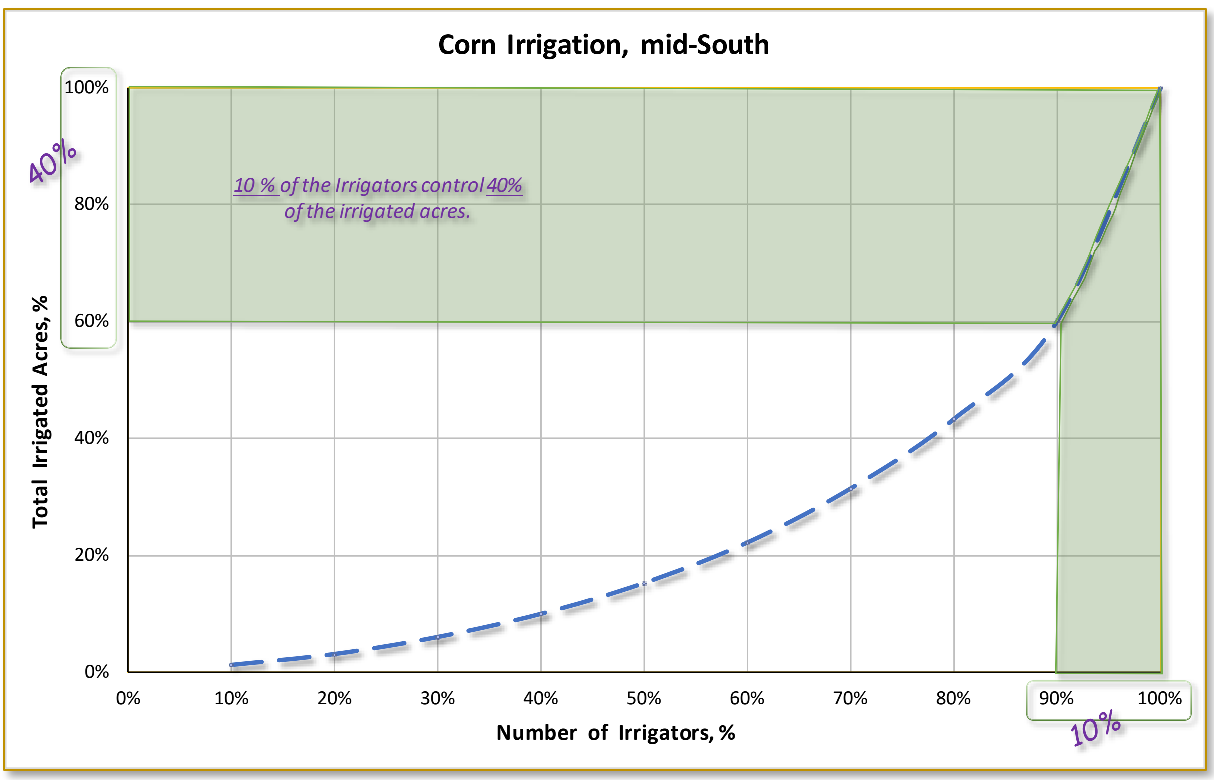


Figure 23. The % of the irrigated corn land controlled by landowners based on their corn farm size in mid-South (illustrating that 10% of the largest corn land holders controlled 40% of irrigated corn acres)

Table 34. The % of land controlled by the top 10 and 20% largest landowners by crop and state

Top 10% of biggest landowners control the following % of acres:				
Location	Corn	Cotton	Soybeans	Rice
All 4 states	39.9%	36.4%	48.7%	36.8%
Arkansas	29.9%	24.1%	43.6%	35.9%
Louisiana	29.2%	21.4%	58.0%	26.1%
Mississippi	40.2%	35.5%	37.8%	37.0%
Missouri	25.9%	31.4%	27.2%	19.3%
Top 20% of biggest landowners control the following % of acres:				
Location	Corn	Cotton	Soybeans	Rice
All 4 states	56.7%	51.8%	62.7%	52.4%
Arkansas	49.5%	42.2%	58.1%	51.2%
Louisiana	48.0%	37.3%	71.1%	42.4%
Mississippi	58.5%	51.3%	56.1%	59.4%
Missouri	41.3%	54.0%	43.7%	36.2%

8.7 Participation in Farm Programs

Many of the respondents had participated in various local, state, and federal conservation programs. The question series, **Q106**, asked about this, specifically inquiring in regards three programs (as well as, allowing an input of an additional one) that they had been involved in during the last five years. This allowed for the respondents to reply affirmatively as being involved in up to four programs.

The mean value for the number of programs that irrigators were associated with was 1.34. Mississippi and Missouri irrigators had higher levels of participation (≈1.35), while Arkansas and Louisiana's rates were a little bit less (≈1.15). In the mid-South region, 27% of the irrigators did not participate in any government conservation program. The range of non-participation was MO (19%), MS (25%), AR (27%), and LA (32%). **Figure 24** is a frequency histogram of numbers of programs people were involved in.

The option to indicate an unlisted conservation program (choice #4) was selected 29% of the time. Programs that were mentioned as other conservation programs multiple times included: CSP (116), NRCS (16), WRP (4), Delta Farm (2), and state cost share (2). Others mentioned a single time were: AWEP, CREP, MRVI, MLBI, MBRI, Soil Bank, Tree Program, Acres for Wildlife, Conservation Incentive, Wildlife conservation, Price protection, Rice stewardship, something with bees, soil erosion, and Corps of Engineers.

Have you participated in any of these federal, state, or local conservation programs in the last five years?		Yes (1)	No (2)	Don't Know (3)	Refused (4)
Q106_1	Conservation Reserve Program (CRP)	ʘ	ʘ	ʘ	ʘ
Q106_2	Environmental Quality Incentives Program (EQIP)	ʘ	ʘ	ʘ	ʘ
Q106_3	Regional Conservation Partnership Program (RCPP)	ʘ	ʘ	ʘ	ʘ
Q106_4	Any other conservation program	ʘ	ʘ	ʘ	ʘ

Q106_4_other (Please specify) ________________

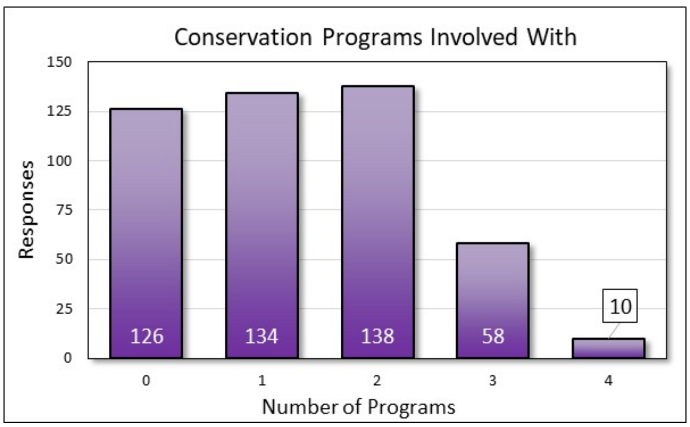


Figure 24. Frequency histogram, number of conservation programs participating

8.8 Yield Levels of Survey Participants

To help establish background regarding the individual's own irrigation skill level, participants were asked to provide their expectant yields for four irrigated crops (see the Question **Q143** series in Text Box 1 below). For all four of these crops and in all four states, participant response in providing these yield estimates was forthcoming, the rate being 91.1%. **Table 35** provides information concerning the number of participants who provided estimates on their yield expectancy; it also tallies the number of responses that fell out of the expected yield norms.

This information about participants' expected yields can be useful to the researcher as a diagnostic tool to:

- Estimate the irrigation competency of the surveyed group against the population at large (c.f., **Table 36**).

- Estimate in-survey differences between assorted items (e.g., pivot versus surface irrigation, schedulers versus non-schedulers, etc.).[16]

What yield expectation do you have on your farms for the following crops?

Q143_1 Corn (in bushels per acre) ______
Don't Know (-1)
Refused (-2)

Q143_2 Soybeans (in bushels per acre) ______
Don't Know (-1)
Refused (-2)

Q143_3 Rice (in bushels per acre) ______
Don't Know (-1)
Refused (-2)

Q143_4 Cotton (in pounds of lint per acre) ______
Don't Know (-1)
Refused (-2)

Text Box 1. Survey question series Q143 re: participant's expected yields

Table 35. Participant-provided yield estimates

	Corn	Cotton	Soybean	Rice
Number of participants who grew crop	294	106	403	229
Number supplying estimates on yield (% of YES respondents providing yield information)	264 (89.8%)	90 (84.9%)	382 (94.8%)	204 (89.1%)
Yields out of expected max/min range	5	2	14	11
Maximum cap	300 bu/ac	1,600 lbs/ac	110 bu/ac	250 bu/ac
Minimum cap	110 bu/ac	700 lbs/ac	38 bu/ac	100 bu/ac

Table 36 compares the participants' reported anticipated yields to that recorded for statewide irrigated crop yields as reported by the USDA for the period 2013 to 2015. The farmer anticipated yields were very close to the recorded four-state region yields for the period 2013 to 2015, other than that the survey participants' soybeans yields were ≈25% higher and their corn yields were ≈15% higher. Other than

[16] Doing so showed significant differences in several ***IBMP***s reported on later.

Arkansas' cotton yields and Louisiana's rice yield, anticipated yields for all crops and all states were higher than the USDA yields.

Table 36. Comparison of anticipated crop yields (w/ & w/out outliers) to USDA/NASS totals
Recorded Rice Yields and the USDA/survey ratio (2013 – 2015). [A]

CORN							
STATE	USDA/NASS State Average Yields [A]				Survey Results		
					Farmer-Anticipated Yield		Sample Size
	2013	2014	2015	2013-2015 Avg.	All Data	Outliners Removed	
	---------- bu/acre --------				---------- bu/acre --------		
Arkansas	147.0	159.0	147.0	166.4	188.1 (1.13)	189.0 (1.14)	106
Louisiana	173.0	183.0	171.0	158.3	178.5 (1.13)	179.2 (1.13)	48
Mississippi	176.0	185.0	142.0	162.4	188.3 (1.16)	188.6 (1.16)	87
Missouri	136.0	186.0	142.0	154.7	202.8 (1.31)	202.8 (1.31)	23
All 4 States	147.0	159.0	147.0	160.4	187.7 (1.17)	188.3 (1.17)	264

COTTON							
STATE	USDA/NASS State Average Yields [A]				Survey Results		
					Farmer-Anticipated Yield		Sample Size
	2013	2014	2015	2013-2015 Avg.	All Data	Outliners Removed	
	---------- lbs./acre ---------				---------- lbs./acre ---------		
Arkansas	1,449	1,579	1,555	1,528	1,258 (0.82)	1,258 (0.82)	27
Louisiana	1,223	1,154	814	1,064	1,157 (1.09)	1,186 (1.11)	14
Mississippi	1,203	1,232	1,021	1,152	1,260 (1.09)	1,260 (1.09)	40
Missouri	968	1,117	1,111	1,065	1,167 (1.10)	1,189 (1.12)	9
All 4 States	1,211	1,271	1,125	1,202	1,234 (1.03)	1,241 (1.03)	90

SOYBEAN							
STATE	USDA/NASS State Average Yields [A]				Survey Results		
					Farmer-Anticipated Yield		Sample Size
	2013	2014	2015	2013-2015 Avg.	All Data	Outliners Removed	
	---------- bu/acre --------				---------- bu/acre --------		
Arkansas	43.5	49.5	49.0	47.3	55.7 (1.18)	56.0 (1.18)	180
Louisiana	48.5	56.5	41.0	48.7	64.4 (1.32)	61.6 (1.26)	54
Mississippi	46.0	52.0	46.0	48.0	57.7 (1.20)	57.8 (1.20)	123
Missouri	36.0	46.5	40.5	41.0	58.4 (1.42)	58.7 (1.43)	25
All 4 States	43.5	51.1	44.1	46.3	57.8 (1.25)	57.5 (1.24)	382

RICE							
STATE	USDA/NASS State Average Yields [A]				Survey Results		
					Farmer-Anticipated Yield		Sample Size
	2013	2014	2015	2013-2015 Avg.	All Data	Outliners Removed	
	---------- bu/acre --------				---------- bu/acre --------		
Arkansas	168.0	168.0	163.1	166.4	179.2 (1.08)	179.2 (1.08)	134
Louisiana	162.2	158.4	154.2	158.3	132.0 (0.83)	147.8 (0.93)	33
Mississippi	164.4	164.9	158.0	162.4	174.3 (1.07)	176.4 (1.09)	31
Missouri	156.2	151.8	156.0	154.7	176.7 (1.14)	176.7(1.14)	6

All 4 States	162.7	160.8	157.8	160.4	170.8 (1.06)	173.6 (1.08)	204

[A] Outlier values were set to equal certain values if above or below set maximum or minimum values (C.f., **Table 35**).

[B] United States Department of Agriculture / National Agricultural Statistics Service. (2016). Crop Production 2015 Summary. Report: ISSN: 1057-7823. Available at: https://www.usda.gov/nass/PUBS/TODAYRPT/cropan16.pdf.

8.9 Surface Shaping

It has been an adage among old-time Extension irrigation engineers in the mid-South that an irrigator needs to first take care of surface drainage problems on his farm before he can really tackle irrigation issues. Within just the bootheel of Missouri there was excavated more cut than was dug excavating the Panama Canal. A particular aspect of surface management that has had much bearing on farming in the mid-South is the adoption of land leveling following WW2 (Figure 71. Adoption rate history of precision leveling in the mid-South).

Laser Guidance. Formerly, land surfaces were modified using land planning. But, the level of precision in slope modification significantly increased with LASER guided technology in the 1970s. The presence of rice cultivation was instrumental in spurring its adoption. LASER guidance used a tripod-mounted laser beacon that was programed to rotate at dialed-in main & side slope angles leading to a land surface plane paralleling the one being scribed in the air by the laser beam. Barring special intervention, the land surfaces were at a constant slope.

Equipment costs were fairly low leading many farmers to purchase their own laser-leveling apparatus. Up to around 2005, the cost of diesel fuel was also low (≈$1 per gallon), steering many surface-irrigated --and then even pivot-irrigated and dryland fields-- to become precision leveled (**Table 37**, Henggeler [1998]). The popular adoption of improved land surface management led to regionwide hydrological changes ensuing from surface entrapment and runoff of rainfall.

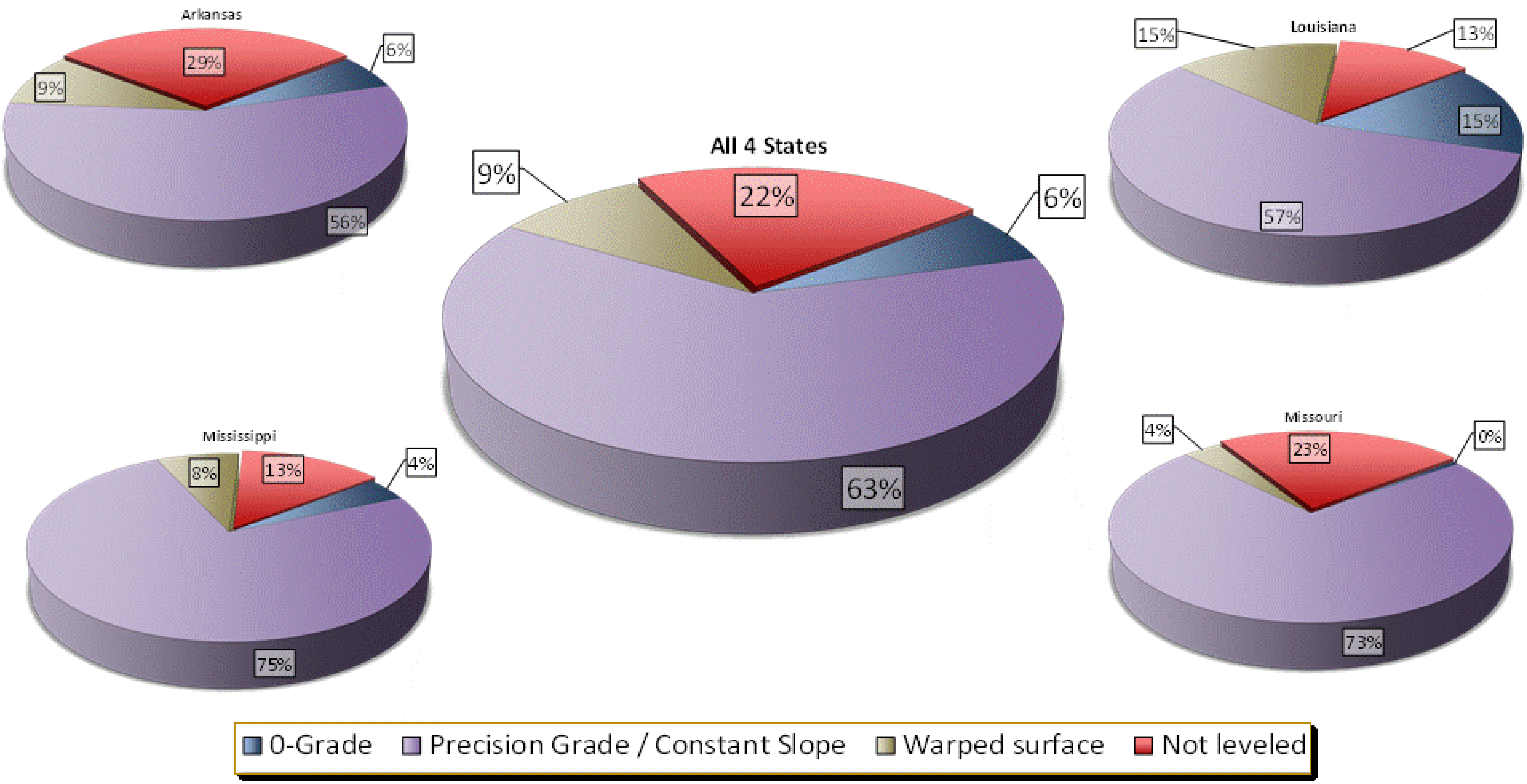
Table 37. Land surface treatments by type of irrigation (S.E. Mo. & N.E. Ark., 1998)

Surface Treatment	Land Class		
	Flood-Irrigated	Pivot-Irrigated	Dryland
Laser-leveled	76%	34%	6%
Land-planed	17%	23%	27%
No dirt Work	6%	42%	62%

GPS Guidance. Later, GPS was used to supply the guidance which now allowed for multi-sloped fields and inclusion of soil structures (berms, roads, pumping platforms, etc.) and cutouts (tail water reservoirs, return flow pits, etc.). The difference between laser- versus GPS-guided enterprises boils down to 2-D land leveling contrasted to 3-D land forming. Also, multi-slope or warped surface leveling reduces the amount of field cut. But equipment costs are now much higher, leading to land forming generally being contracted out to custom operators.

Table 38. Land surface finishing by state.

Locale	0-Grade			Precision Grade / Constant Slope			Warped surface			Not leveled		
	TOTAL (acres)	N	MEAN (acres)	TOTAL (acres)	N	MEAN (acres)	TOTAL (acres)	N	MEAN (acres)	TOTAL (acres)	N	MEAN (acres)
Arkansas	28,620	72	397.5	267,674	161	1,662.6	44,060	58	759.7	138,562	122	1,135.8
Louisiana	20,794	26	799.8	76,411	65	1,175.6	20,400	22	927.3	16,924	36	470.1
Mississippi	11,375	26	437.5	210,110	116	1,811.3	21,672	33	656.7	38,035	76	500.5
Missouri	360	2	180.0	50,010	20	2,500.5	2,450	3	816.7	16,030	16	1,001.9
All 4 States	61,149	126	485.3	604,205	362	1,669.1	88,582	116	763.6	209,551	250	838.2



8.9.1 An Influencing Factor on Surface Shaping:

Multi-slope land forming was pioneered to the level it is at now by Graeme Cox, a PhD agricultural engineer and sugar cane grower from Australia. After employing laser-guided leveling and irrigating those fields for twenty years, he moved up to precision GPS leveling, largely to decrease the amount of cut in a field. He developed the software (OptiSurface) that not only does the standard cut-fill calculations, but calculates drainage, hydrology and water flow parameters, allowing a user to get a full understanding of how water will react across the surface of a field.

GPS land forming companies are all benefitted from innovations from other companies. Multi-slope land forming equipment was used to restore productivity on many of the inundated 130,000 acres of Missouri farm land that was flooded in 2011 after the Army Corps of Engineers blew out part of the levee system on the Mississippi River (Deere, 2011).

Around 2000 a regional headquarters for OptiSurface was set up in Jonesboro, Arkansas. **Figure 25** shows the acreage of multi-slope, land leveled fields in the mid-South and the location of the OptiSurface regional headquarters in Jonesboro, Arkansas.

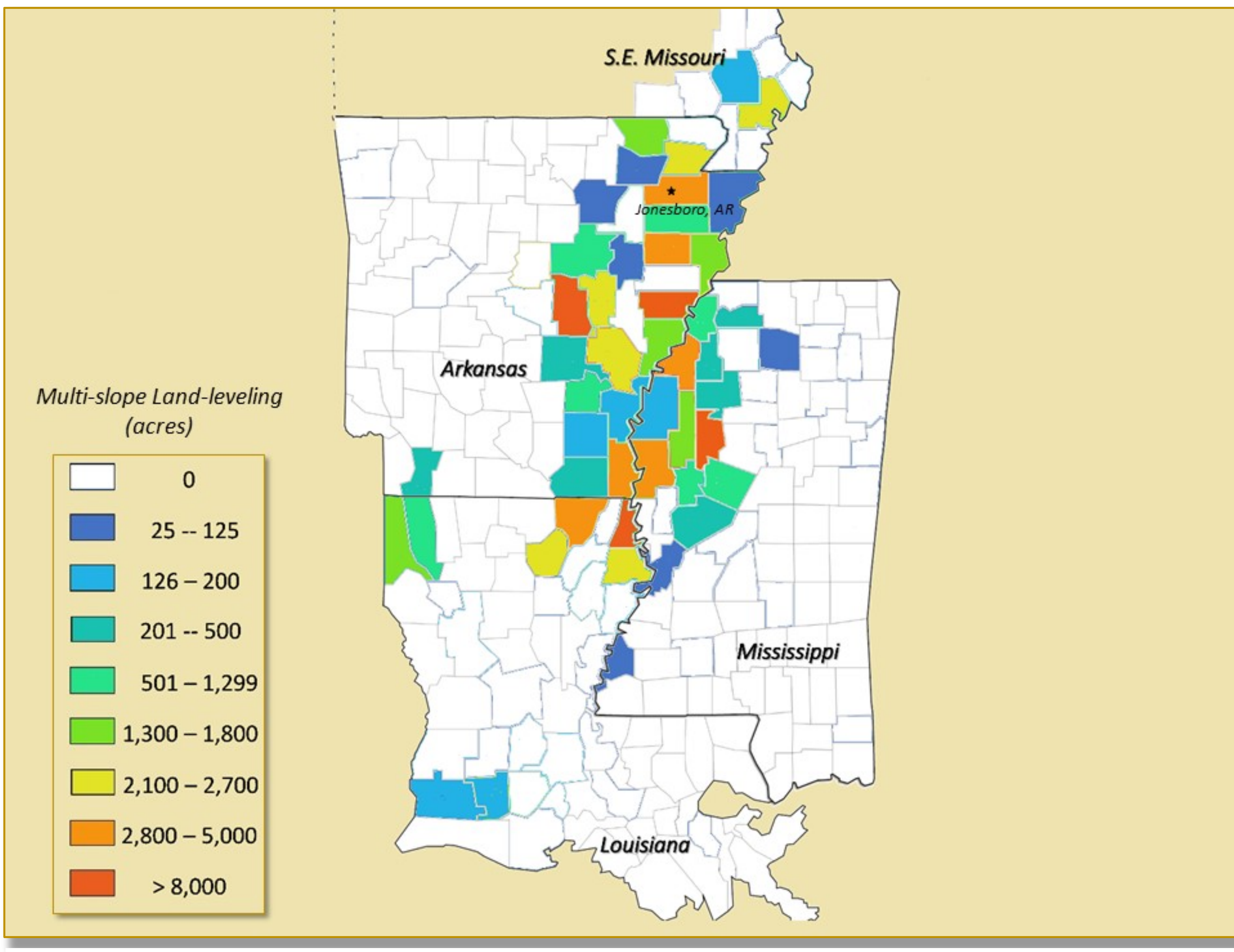


Figure 25. Map, acres of multi-slope per county and location of Opti-Surface regional headquarters

9 Water Resources

9.1 Concerns regarding Water Sustainability

The survey contained four questions that elicited information from the respondent regarding concerns he might have on the sustainability of water resources. Question **Q13** demonstrates that effort was clearly made to establish the direction of water level change being asked/reported about was understood by the irrigator (this can at times be confused); this enquiry is about changes in water level at their farm. The next question, **Q14**, queries about perceived groundwater shortage problems, statewide and on the respondent's own farm. Questions **Q15** and **Q16** attempt to quantify the situation and are similar, the former, referring to "your farm" and the latter to "your state" -- they ask the irrigator to rate the level of severity on a scale of 1 to 5 (1 meaning 'no problem' and 5 meaning 'severe problem).

Q13
For the wells used on this operation, how has the depth-to-water changed over the last five years?
(Note that a depth-to water increase means water levels are dropping)

ʘ Depth-to-water did not change (1)
ʘ Depth-to-water increased (2)
ʘ Depth-to-water decreased (3)
ʘ Don't Know (4)
ʘ Refused (5)

Text Box 9. Survey question Q13 re: participant's opinion on water level changes

In your opinion, do you have a groundwater shortage problem		Yes (1)	No (2)	Don't Know (3)	Refused (4)
Q14_1	… on your farm?	ʘ	ʘ	ʘ	ʘ
Q14_2	… on your state?	ʘ	ʘ	ʘ	ʘ

Text Box 10. Survey question series Q14 re: participant's opinion on groundwater shortage

Q15
On a scale of 1 to 5, with 1 meaning 'no problem' and 5 meaning 'severe problem,' how would you rate the groundwater shortage problem on your farm?)

- ʘ 1 (1)
- ʘ 2 (2)
- ʘ 3 (3)
- ʘ 4 (4)
- ʘ 5 (5)
- ʘ Don't Know (6)
- ʘ Refused (7)

Text Box 11. Survey question Q15 re: participant ranking groundwater shortage problem

Changes in water table. **Table 39** shows that overall in the mid-South, only 13.1% of the 412 irrigators offered an opinion on whether water levels on their farm were changing or not, felt that it was dropping. Missouri irrigators were less likely to feel levels were dropping, and Arkansas irrigators the most likely. The percentages of irrigators feeling that water levels were dropping were 0, 12, 19, and 29%, respectively, for MO, LA, MS and AR.

Table 39. Farmers' depth-to-water change (Q13) in their irrigation wells & their percent of sample

Location	Survey Response					
	Depth-to-water increased [A] ☹	Depth-to-water did not change 😐	Depth-to-water decreased ☺	Refused	Don't Know	Total
Arkansas	26 14%	107 57%	54 29%	1	11	199
Louisiana	7 9%	59 79%	9 12%	1	17	93
Mississippi	20 16%	84 65%	25 19%	1	18	148
Missouri	1 5%	20 95%	0 0%	0	5	26
All 4 States	54 13%	270 66%	88 21%	3	51	466

[A] Note that a depth-to water increase means water levels are dropping.

Local and statewide groundwater concerns. The survey asked farmers to scale their feelings on groundwater shortages, both on their own farm and for the state at large. A scale of 1 to 5 was used, with 1 meaning 'no problem' and 5 meaning 'severe problem'. Respondents appeared more optimistic regarding their own individual farm than they did for the state. However, farmers appeared very reluctant to answer the question when it regarded their own farm (a response on concern level for the state was almost five times as forthcoming). **Table 40** reports the results solicited from questions ***Q14*** to ***Q16***.

Table 40. Perceived groundwater shortage severity by irrigators for their own farm and for their state

STATE	For Your Farm	For Your State
Arkansas	3.32 (n = 31)	3.60 (n = 139)
Louisiana	2.00 (n = 6)	3.25 (n = 16)
Mississippi	2.63 (n = 8)	3.33 (n = 48)
Missouri	---	2.50 (n = 2)
All 4 States	3.02 (n = 45)	3.50 (n = 205)

Figure 26 shows a graphic presentation of farmers' concept on the level of the statewide groundwater severity problem. In general, irrigators adjacent or near the northern reaches of the Mississippi River on the western side were not as concerned about shortage problems. The only exception for this was Cape Girardeau County in Missouri; it should be noted much of this county lies outside the range of the Mississippi River's delta.

Growers on the river's eastern side (they all were in Mississippi), had mild levels of concern. In Arkansas, concerns of the irrigators about their state water shortage appeared to increase both in the downstream direction and, laterally, in distance from the river.

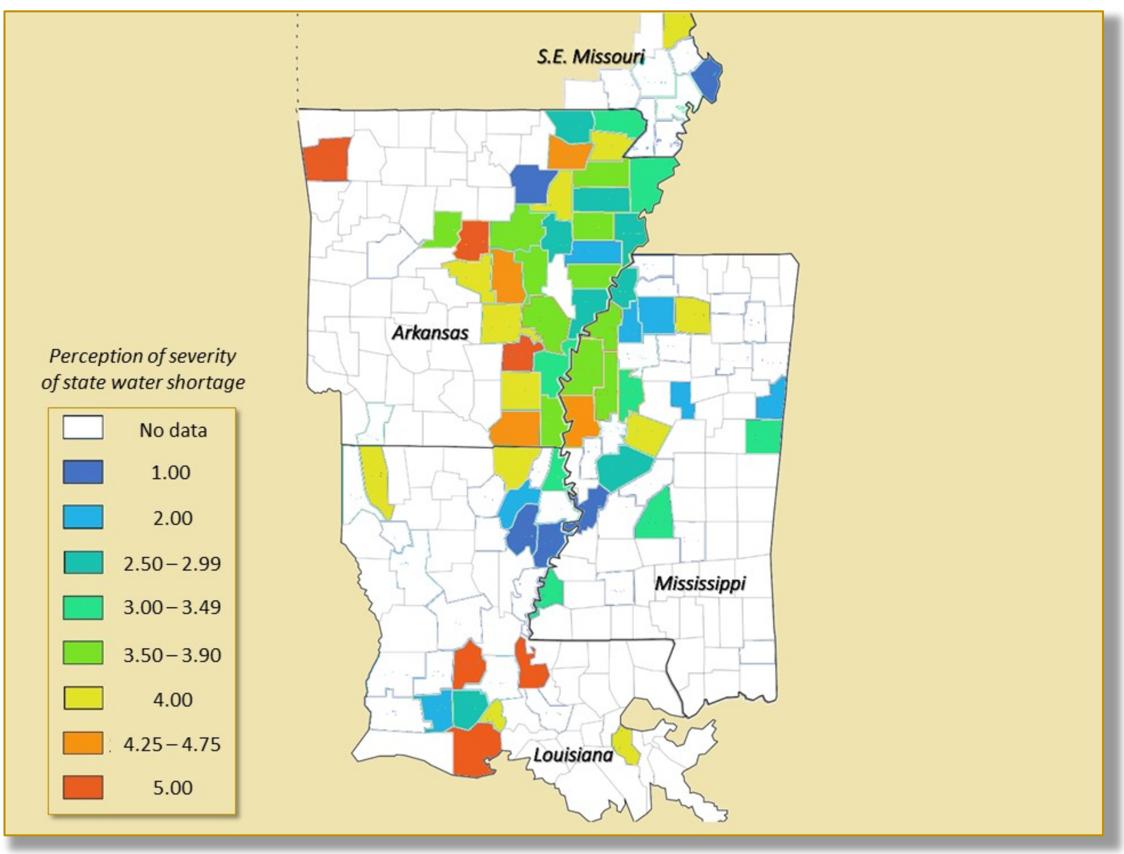


Figure 26. Map, average perceptions of irrigators of groundwater shortage in their state with 1 being "no problem" and 5 being a "severe problem"

Additionally, two subsequent questions in the survey (the ***Q_10*** and ***Q_11*** series), asked about the number of diverse sources of water irrigators used (c.f., **9.2** *Source of Irrigation Water* where the types of water sources will be discussed in more depth); it appears that has the level of severity rises, the number of sources increases. **Figure 27** shows the relationship of the level of concern regarding water shortage and the number of various water sources employed by the irrigator.

Northern Economics (2017) noted for the Arkansas dataset that:

> *The survey shows that there are roughly just as many small farms using ground water as large farms. However, results indicate that large farms (Greater than 1,000 acres) are more likely to use surface water than small farms and are also more likely to engage in various recovery and storage activities.*

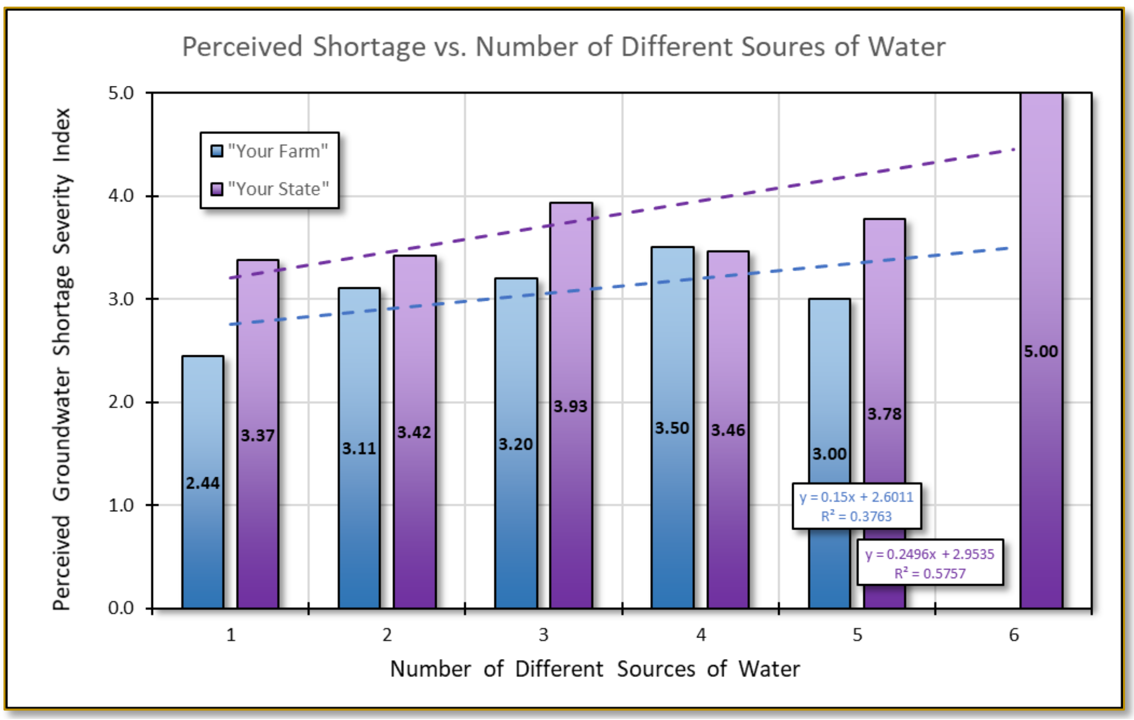


Figure 27. The perceived groundwater shortage index for “your farm” & “your state” vs. number of water sources used

9.2 Source of Irrigation Water

Water used for irrigation came from a variety of sources. The participants were asked to report on the percentages of water emulating from the six listed possible sources in the **Q11** series of questions.

(W)hat percentage of this water comes from …
Q11_1 Groundwater ______
Q11_2 Water withdrawn and immediately and used from a surface water source such as a stream or bayou ______
Q11_3 Water withdrawn from a surface water source such as a stream or bayou and stored in a reservoir ______
Q11_4 Water withdrawn from a surface water source such as a stream or bayou and stored in a reservoir with a tail water recovery system ______
Q11_5 Water recycled on field by reservoir or tail water ditch no outside source
Q11_6 Water purchased from an irrigation district ______

Text Box 12. Survey question series Q11 re: participant's sources of irrigation water

As an aggregate, almost a fifth of the irrigation in the four states came from non-Groundwater sources. Groundwater, the largest water source, supplied 79.5% of the irrigation water, then followed by directly tapped streams (no impoundment involved) (11.1%); stream water that was stored on-farm in reservoirs prior to being used supplied 3.2% of the irrigation. Thus, in full, stream water can be credited with suppling 14.3% of the water used, and this stream contribution would most likely be higher, since unknown amounts of it ends up in tailwater pits, to be used later. This joint reservoir-tail pit water contribution was 3.3% of the total. These impoundment structures also were utilized to recover on-farm captured water (2.4%). Water district supplies, only used in AR, provided just 0.5% of the total. **Figure 28** is a graphical depiction of the sources of irrigation water for each of the four states.

Missouri had the highest percent of ground water utilization (98%); followed by MS, LA, and finally by AR with percentages of 84, 74, and 68%, respectively. When contrasted with national trends, the mid-South's supply of irrigation water has a higher reliance on groundwater (79% versus 64%) than the nation as shown in **Figure 29**. Stakeholders should keep in mind that the reliance of groundwater for irrigation can have several downsides, such as, sustainability and that it is inherently more expensive. However, the validity of this caveat can vary for several reasons; a case in point is Missouri (98% utilization), where groundwater is not expensive and, save intra- or interstate litigations, it remains sustainable.

While most farmers (55.8%) had just a sole source of water, many had two, three, and up to six separate sources of water. Arkansas was the state that utilized the most sources for irrigation needs. Missouri was the least with 89% of producers having just a sole source (groundwater), the remainder of whom had just two sources. Results are seen in **Table 41**.

Table 41. The average number of water sources (Q11) participants used for irrigation

Location	Number of water sources for irrigation				
	Average number of sources	1	2	3	>=4
Arkansas	1.98	46.2%	27.6%	13.6%	12.6%
Louisiana	1.42	63.4%	33.3%	2.2%	1.1%
Mississippi	1.51	58.1%	32.4%	5.4%	2.7%
Missouri	1.12	88.5%	11.5%	0.0%	0.0%
All 4 States	1.67	55.8%	29.4%	7.9%	6.4%

The actual portions that these six sources of water contribute to the four mid-South states' own individual irrigation enterprise is clearly visualized in **Figure 28**. Already alluded to, the development and use of additional sources water to meet irrigation needs may reflect that fact that a farmer and his state have concerns about, as the questionnaire put it, "the groundwater shortage problem."

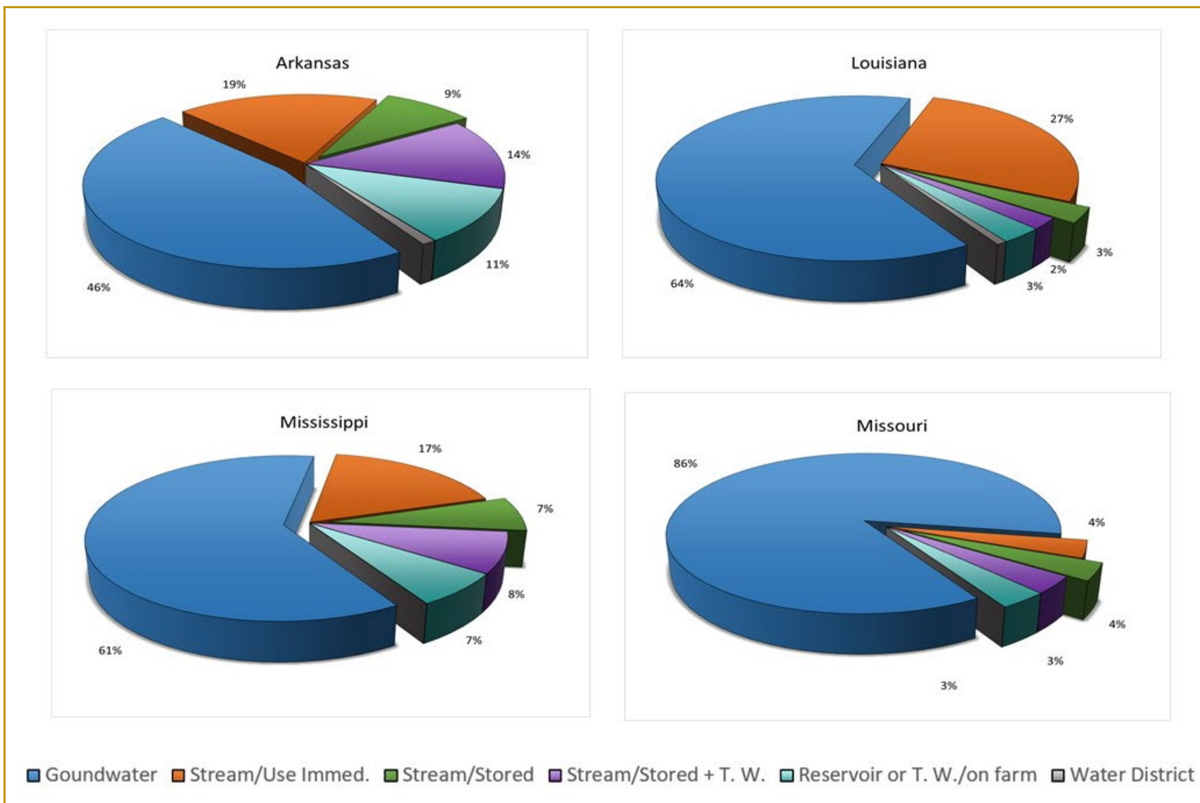


Figure 28. State average irrigation water resources on rice farms. Gwr = ground water; Str (D) = stream (direct); Str (S) = stream (stored); Str (S) + TWR = stream (stored) + Tail Water; Rsvr/Twr (n.o.s.) = Reservoir or Tail Water (no outside source); WD = Water District

The data used to derive the information for **Figure 28** came from the responses to the ***Q11*** series of questions regarding the sources for their water for irrigation. This question series enjoyed excellent participant cooperation, and the six queried-for water source component portions summed to equaled 100% in 99.6% of the instances. However, using this methodology of tallying the 466 individual irrigators' list of water sources that they utilized to collectively assign state and regional water sources has a serious flaw: land ownership among participants varied from a low of 5 acres up to a high of 20,000 acres based on ***Acres***$_{CG}$ calculations (and still more drastically when ***Acres***$_{IM}$ values were used).

Therefore, the shares for the component portions constituting irrigation water makeup were recalculated on a weighted basis reflecting the amount of land that the participant had reported and is shown in **Table 42**. The ***Acres***$_{CG}$ values were employed. Using this procedure, the groundwater contribution increased from the former 79.2% to a new level of 81.0%. The response rate decreased to a new level of 94.8% since the ***Acres***$_{CG}$ dataset had some added missing values.

Table 42. Component portions of water source contribution based on two separate calculation procedures for the mid-South irrigation water.

Methodology		Ground-water	Stream (Used Immediately)	Stream (Stored)	Stream (Stored) + Tail Water	Reservoir or Tail Water - no outside source	Water District Purchase
Calculation Procedure	Response Rate	(***Q11_1***)	(***Q11_2***)	(***Q11_3***)	(***Q11_4***)	(***Q11_5***)	(***Q11_6***)
∑ Component choices of all participants	99.6%	79.2%	11.0%	3.2%	3.3%	2.4%	0.5%
∑ Component choices of all participants (weighted by each's Acres$_{IM}$)	94.8%	81.0%	9.9%	2.9%	3.6%	2.4%	0.3%

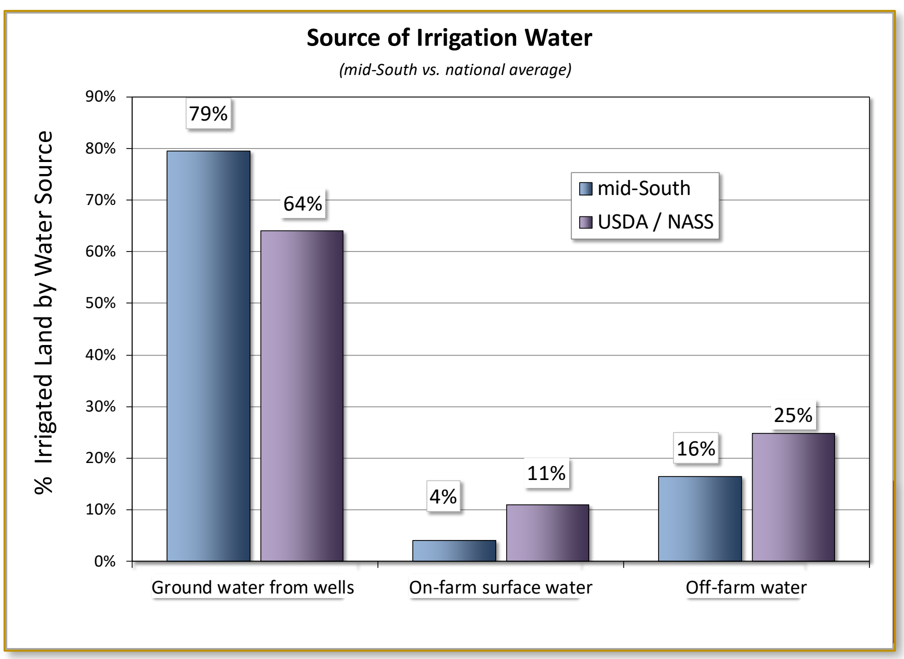


Figure 29. Source of irrigation water for mid-South vs. national average

9.3 Irrigated Area per Pump

Question ***Q69*** asked the farmers the quantity of irrigation pumps they owned (see below).

> Q69
> How many irrigation pumps are on your farms? ______
>
> Don't Know (1)
> Refused (2)

The average number of pumps owned by farmers, broken down by state, is seen in **Table 43**. In the mid-South region, irrigators on average owned 21.7 pumps each. The range of number of pumps owned by participants was from just one up to a high of 220.

This Table 43 also shows the average number of acres irrigated per pump. Regionwide a single pump would support approximately 120 irrigated acres. Arkansas had the highest density of pumps (103.7 acres for every pump) and Louisiana the least dense (156.4 acres for every pump). **Figure 30** is a histogram showing the range districtwide of acres supported per pump. The bin that included 80 to 106 acres per pump, is the most populous one and represents 23% of the total.

The values found in the *USBIS* are like those found by Henggeler (1997, etc.) who had annually collected data in irrigation surveys and at conferences (from 1997 to 2010) from framers in the Missouri bootheel and NE Arkansas. Over the years it was discovered that there are various benefits that can be derived from information regarding on-farm pumps, along with the associated expected irrigated acreage the units service:

- Over time, the reported values of acres/pump continued to remain consistent.
- Irrigators appear to readily know the number of pumps[17] they have, and generally are willing to provide this information.
  - On the other hand, irrigators appear to be less forthcoming in providing information regarding the number of irrigated acres they have, especially if it is a large amount.
- The pump-acreage relationship is bi-directional:
  - knowing pump number → irrigated acres
  - knowing irrigated acreage → number of pumps
- Many mid-South states register information on irrigation wells.
  - Well drillers are dependable in registering the wells they drill, as their licenses are at stake.
  - The dates and locations of the wells are provided, so that information on historic withdraws and areas being pumped can be estimated.

[17] "Pumps" referred to here just reflect those in wells.

Table 43. Average number of pumps, irrigated land area, and acres / pump per respondent

Location	Number of Pumps Owned				Land - Pump Ratio	
	Average (n)	Std	Max	Min	Land (acres)	Acres/ Pump
Arkansas	27.1 (198)	27.88	220	1	2,492	103.7 (193)
Louisiana	9.7 (88)	9.89	42	1	1,582	156.4 (88)
Mississippi	21.0 (146)	23.99	120	1	2,291	120.3 (146)
Missouri	28.6 (21)	36.86	167	3	2,665	118.3 (21)
All 4 States	21.7 (448)	25.46	220	1	2,267	119.7 (448)

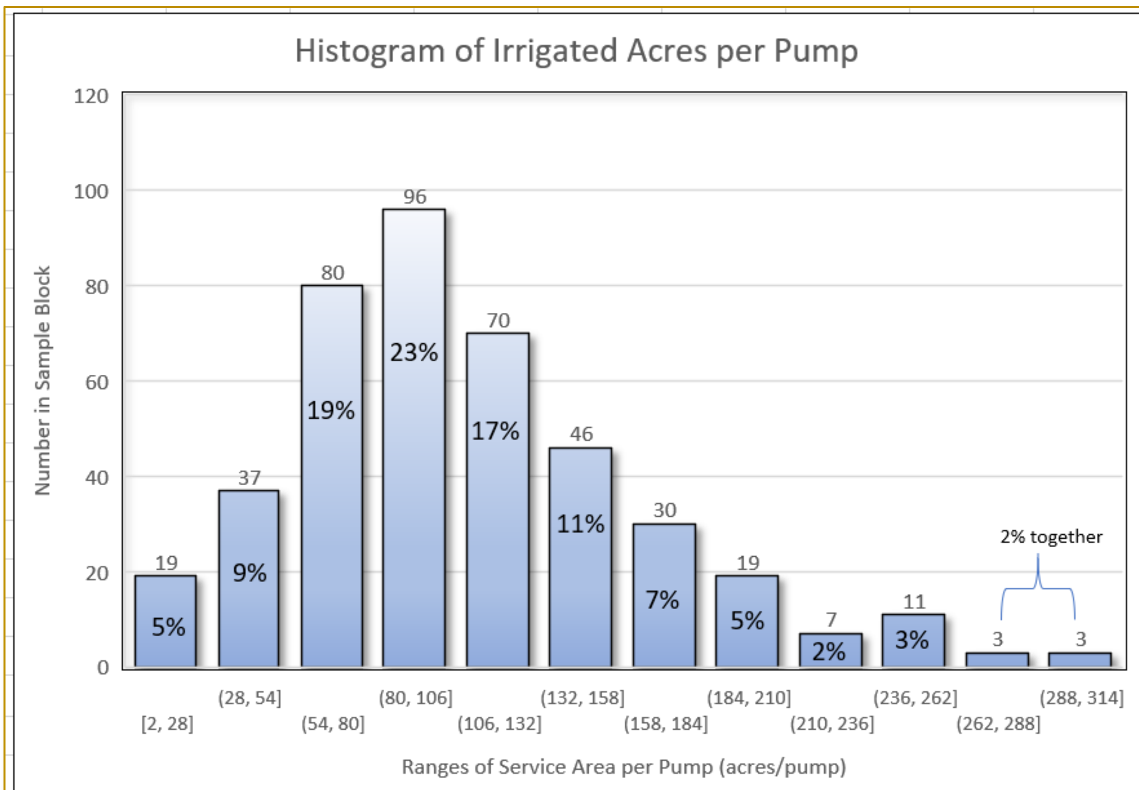


Figure 30. Histogram of irrigated acres per pump

9.3.1 Further Insight Regarding Pump Number

Within the *USBIS,* as previously reported, the two main tallying methods for ascertaining individuals' irrigated acreage --as well as the survey's total—were the ***Acres$_{IM}$*** and ***Acres$_{CG}$*** values; these were not in full agreement, with the latter method being about 50% less. However, as Henggeler had found earlier in annual *Bootheel Irrigation Surveys*, a high percentage of participant farmers in the survey (96.1%) likewise provided data regarding their number of irrigation pumps. **Table 44** shows the percentage of participants by state who provided data on the number of pumps they had. Thus, a backdoor method would be available to estimate irrigated acreage, in cases where it is not supplied or appears incorrect.

Table 44. Farmers providing data on the number of their pumps.

Location	Non-zero Numbers	Value = zero	“Don't know”	“Refused”	Total Responses
Arkansas	193 (97.0%)	2	4	0	199
Louisiana	88 (94.6%)	0	4	1	93
Mississippi	146 (98.6%)	2	0	0	148
Missouri	21 (80.8%)	1	3	1	26
All 4 States	448 (96.1%)	5	11	2	466

10 Factors Influencing Practice Adoption by Irrigators

In the survey, six specific irrigation practices were investigated in detail to ascertain reasons for why, or why not, those practices were adopted, and in some instances, how they were financed. Data had also been collected on acres involved and when the practice was first adopted. These in-depth analyses on adoption behavior all involved gravity irrigation.[18] These practices were:

- Tailwater recovery / storage reservoirs.
- Computerized hole selection (CHS).
- Surge irrigation.
- Precision leveling.
- Zero grade.
- Multiple Inlet Rice Irrigation (MIRI).

In the survey the reasons for adopting or not adopting, and the funding sources were presented in a menu fashion; in that menu was also the opportunity to choose OTHER, whereby additional responses could be recorded. Reasons for or not using a practice might be economic-, resource-, or social/political-based. In some cases, the participant was asked where the inspiration for trying the practice came from (e.g., Extension, industry, a neighbor, an idea he had, his own on-farm trial, etc.).[19] These ***IBMP***s are looked at individually, as well as, collectively, to try and determine the motivating reasons farmers adopted ***IBMP***s. **Table 45** shows these ***IBMP***s that were studied, and the data collected about with associated questions used.

Table 45. Adoption parameters and questions regarding various ***IBMP***s

Practice	Questions / Question Series Involved				
	Adoption Reasoning			Total Acres	When Started
	Why Adopted	Why NOT Adopted	Funding Sources		
Tailwater recovery / storage reservoirs [A]	Q25	---	Q26_1 … Q26_6	Q18	Q19, Q24
Computerized hole selection [B]	Q39	Q40	---	Q37	Q38
Surge irrigation [B]	Q44	Q46	Q45_1 … Q45_4	Q42	Q43
Precision leveling [C]	Q50	Q52	Q51_1 … Q51_4	Q47_2, Q47_3, Q97_1	Q49
Zero grade [B]	---	---	Q99_1 … Q99_5	Q47_1, Q97_3	Q98
Multiple Inlet Rice Irrigation [B] [C]	Q101	Q102	---	Q97_6a, Q97_6b	Q100

[A] The Q105 series asked about energy savings for Tailwater Recovery System and Storage Reservoir separately.
[B] The Q105 series asked about energy savings.
[C] The Q97_6 series asked how they interact.

Since these practices generally involve a form of gravity irrigation (i.e., furrow, flood or basin), the actual percentage rate of adoption of these practices should just involve farmers having those types of systems on his farm. In order to determine the total number of farmers using at least some amount of gravity irrigation, the responses from several groups of survey questions were examined; from two to five

[18] Ancillary information was also collected on other irrigation practices, such as pivots, but not in so much detail.
[19] This question is similar in regard to a companion study on Arkansas participants.

component questions were involved in the calculation methods. If, in these groupings, should just one of the component parts be positive, that individual was affirmed as being in the gravity irrigation group.

First, responses to two questions asking farmers if they had ever irrigated field row crops with flood irrigation or border irrigation, ***Q27*** and ***Q29***, respectively, were examined; if either was positive then that farm was considered to use gravity irrigation. This group was expanded reflecting the fact that rice growers should also to be included, thus farmers who had indicated that they were rice farmers (***Q3_4*** [*Do you produce rice under irrigation?]*) were included in the matrix. Again, if just one of the three questions had a positive response then that farm was deemed a gravity irrigation user.

Those two summaries involved determining users of gravity irrigation based on how GROWERS IDENTIFIED THEMSELVES. However, when acreage values were entered (via questions ***Q28b, Q28c***, ***Q30***, and ***Q137_4***) it became apparent that the number of gravity users was actually 10 to 20% higher than shown by the identity method. Also, since the practices of TWR, CHS and surge irrigation are less likely to involve rice, the gravity irrigation sums of the column second from the right in **Table 46** are more appropriate.

Table 46. Total gravity irrigated farms determined using four summation methods

Locale	Total People in Survey	Methods to determine if participant uses gravity irrigation			
		Underplays Number [A]		Truer Estimate of Number	
		A single positive response on Q27 or Q29	A single positive response on Q27 or Q29 or Q3_4	A single positive response value on Q28b or Q28c or Q30 [B]	A single positive response value on Q28b or Q28c or Q30 or Q137_4 [C]
Arkansas	199	150	172	188	190
Louisiana	93	29	59	61	87
Mississippi	148	76	85	129	130
Missouri	26	13	14	19	19
All 4 States	466	268	330	387	426

[A] Many participants indicated they used flood irrigation or border irrigation or grew rice, and then entered no acreage amounts.
[B] Estimate for TWR, CHS and surge.
[C] Estimate for precision level, zero grade and MIRI.

In a few cases, some questions regarding practice adoption that were posed appeared to have been misunderstood or did not invoke full answers from the farmers. For example, there were several ways to calculate the total number of people using a certain practice: do you use? Yes/No; participant providing the number of acres involved; participant providing the funding source, etc. This number was small and estimated to be 5%.

10.1 Funding Sources

On four of those practices, the sources of funding were asked about in more detail: on-farm water storage, surge, precision leveling, and zero grade. Two of the menu choices involved personally funding of the investment (paid cash/reinvestment of farm profits and bank loan), while the others were of a grant nature (**Table 47**). The farmer had the opportunity to choose more than one source of funds. If multiple choices were involved, the percentage share of each was not provided.

Table 47. Funding sources for four ***IBMP***s

Funding Source	Funded Irrigation Practices			
	Tailwater Recovery Storage Reservoir Systems	Surge irrigation	Precision Leveling	Zero Grade
Paid cash or Reinvestment of farm profits	Q26_1	Q45_1	Q51_1	Q99_1
Bank loan	Q26_2	Q45_2	Q51_2	Q99_2
Federal program cost share such as NRCS	Q26_3	Q45_3	Q51_3	Q99_3
State tax credit program	Q26_4	---	---	Q99_4
Other	Q26_5	Q45_4	Q51_4	Q99_5
Received No Funding	All of the above were void			

A large number of growers had not put the practice in place; those that had utilized up to three different sources of money for the project.

Table 48. Percentage funding of TWR systems & number of sources

Tailwater recovery systems / storage reservoirs				
Locale	Fully self-financed	Used funding sources		
		Number of Funding Sources		
		1	2	3
Arkansas	53%	36%	10%	1%
Louisiana	81%	17%	2%	0%
Mississippi	69%	28%	3%	1%
Missouri	88%	12%	0%	0%
All 4 States	66%	28%	6%	1%

Table 49. Type of funding source

Locale	Type of Funding Source				
	Cash	Bank Loan	Federal incentives	State tax credit	Other
Arkansas	19%	6%	27%	4%	3%
Louisiana	15%	1%	2%	0%	3%
Mississippi	17%	2%	14%	1%	2%
Missouri	12%	0%	0%	0%	0%
All 4 States	17%	3%	16%	2%	3%

10.2 Reasons for Adopting

Participants were not specifically asked about adopting zero grade, however, the question on why precision leveling was adopted should evoke similar responses. Both practices of tail water recovery and storage reservoirs were combined into a single interrogatory. The three questions regarding surge, CHS and MIRI all had similar menu choices (see first box below). This makes constructing an overall ranking on motivating reasons for choosing an ***IBMP*** more straightforward.

The menu of possible responses for the tail water recovery/storage reservoirs option and the precision leveling option follow below. Factors for starting to use a practice could be economic-based, resource-based, farm management-based (e.g., irrigation is easier or improves farm drainage), social/political-based (reduce risk of regulation), as well as, coming about through education (self and agency).

Note that only a single reason could be offered.

Q39 or Q 44 or Q101

What is the primary reason you started using **CHS** or **surge** or **MIRI** on your farm?

- ʘ Profit allowed for new investment in technology (1)
- ʘ Experienced water shortage on farm, needed to increase capacity (2)
- ʘ Heard about this technology from a neighbor (3)
- ʘ Learned about this technology at an Extension meeting (4)
- ʘ Learned about this technology from an industry meeting (5)
- ʘ I wanted to reduce input costs (6)
- ʘ I tried it on my farm and saw the benefit (7)
- ʘ Other (8)
  - Q101_other (Please specify) ____________________
- ʘ Don't Know (9)
- ʘ Refused (10)

Q25

What is the primary reason you started using a **tailwater recovery system** or **storage reservoirs**?

- ʘ Groundwater was no longer sufficient (1)
- ʘ Financial assistance was available (2)
- ʘ Landlord converted, it was not my decision (3)
- ʘ Desired to reduce irrigation costs (4)
- ʘ Desired to reduce risk of regulation or water shortage (5)
- ʘ Other (6) (*Please specify*) ____________________
  - ʘ None of these (7)
  - ʘ Don't Know (8)
  - ʘ Refused (9)

Q50

What is the primary reason you started using **precision leveling**? Was it because...

- ʘ Government assistance was available to defer the cost (1)
- ʘ Irrigation water was limited (2)
- ʘ It improves drainage on my farms (3)
- ʘ It makes irrigation easier (4)
- ʘ It improved my profitability (5)
- ʘ I could afford it, because it became more economical to do (6)
- ʘ Other (7) (*Please specify*) ____________________
  - ʘ Don't Know (8)
  - ʘ Refused (9)

10.2.1 Tailwater recovery / storage reservoirs

The two similar ***IBMP***s of tailwater recovery systems and storage reservoirs were combined together for this analysis (**Table** 50). Of the nearly 400 non-rice growing respondents who employed some method of gravity irrigation, nearly 40% had TWR systems on their farm lands. The source of funding was almost equal between being totally self-funded and financed using publicly available funding.

Table 50. Funding sources for Tail Water (TWR) Recovery Implementation

Locale	Gravity Irrigated Farms	TWR -Totally self-financed	TWR-Mostly pubic-financed	TWR-Self- + public-financed	Nothing Installed
	Number	% of Gravity-Irrigated Farms			% of G-Irrigated Farms
Arkansas	191	17%	24%	8%	51%
Louisiana	61	21%	7%	2%	70%
Mississippi	131	18%	14%	4%	65%
Missouri	19	16%	0%	0%	84%
All 4 States	402	18%	17%	5%	60%

Locale	GRAVITY non-Rice	Did not have TWR		TWR w/ 1 Source		TWR w/ 2 Sources		TWR w/ 3 Sources	
		(N)	(%)	(N)	(%)	(N)	(%)	(N)	(%)
Arkansas	188	95	50.5%	71	37.8%	20	10.6%	2	1.1%
Louisiana	61	43	70.5%	16	26.2%	2	3.3%	0	0.0%
Mississippi	129	83	64.3%	41	31.8%	4	3.1%	1	0.8%
Missouri	19	16	84.2%	3	15.8%	0	0.0%	0	0.0%
All 4 States	397	237	59.7%	131	33.0%	26	6.5%	3	0.8%

The reasons given for adoption varied. **Table 51** sorts the various reasons for adopting this practice of on-farm water storage broken into general categories by various states, as does **Figure 31**. Economic factors were pivotal throughout the region and were given by producers in nearly half the cases. Water shortage concerns were most prevalent in Arkansas. Nearly a third of the respondents used the OTHER option to voice their particular adoption reasons (**Table 52**). Other than Missouri, 2-5% of the farmers in those other states indicated from the menu of options that they themselves had not actually installed the water storage system, but instead had "inherited" it when moving into the farm (and this percentage is actually higher since such is mentioned under OTHER).

The TWR projects were self-funded in 66% of the cases. Funds came from one, two and three outside sources in 28%, 65, and 1%, respectively (**Table 48**).

Table 51. Main reasons given for adopting on-farm storage of water

Locale	Groundwater shortage	Avoid regulation or water shortage	Financial $ available or reduce op. cost	Other / None of these	Don't Know / Refused
Arkansas	10.1%	14.1%	45.5%	29.3%	1.0%
Louisiana	5.3%	5.3%	42.1%	47.4%	0.0%
Mississippi	3.9%	17.6%	49.0%	27.5%	2.0%
Missouri	0.0%	0.0%	25.0%	75.0%	0.0%
All 4 States	7.5%	13.9%	45.7%	31.8%	1.2%

Table 52. Other reasons cited for adopting the practice of on-farm storage

AR	LA	MS	MO
Reasons for Adopting			
• Improve quality of farm by using warm water • It was already in place when I started • Respondent's father implemented in the 1940s as an experiment • Allowing the salt to settle on the ground • To control flooding • Reservoir is used because of salt problem • Planting plants that need more water • Federal conservation • Increase water supply • Wanted to try it • Just to be a better person to the environment • Best management practice • Cheapest way to get started • Warmer water crops do better when we use the tailwater and it is cheaper • Better water quality • More convenient • Help out some wells • To stop using floured • Water just sitting there • Conservation of water • It is a natural break, so it is always there • Because of salt in the ground • More beneficial for recycling water • Conservation and cheaper to pump • Ease of use • Accessible and free • Quality of water	• Availability of land • Conservation of water • Just natural • Surface water is a better quality • It was already in place when I started • Easiest way to get water • It was already in place when I started • Maintain level of the lake • It is beneficial for the farm	• Wanted to get water out of every source • Worked well with the land • Protect the groundwater source • Helps with the land and animals • For raising sod, you have to use reservoir • Built the lake to irrigate with • Availability of land • Easiest way to get water • Do this instead of putting down a well • Conservation of water • It is beneficial for the farm • It is beneficial for the farm • Availability of land • Maintain level of the lake	• We need it to keep water off the low ends of the field • Cost efficient and water is warmer • Did not have a deep well at the time

Tailwater recovery / storage reservoirs

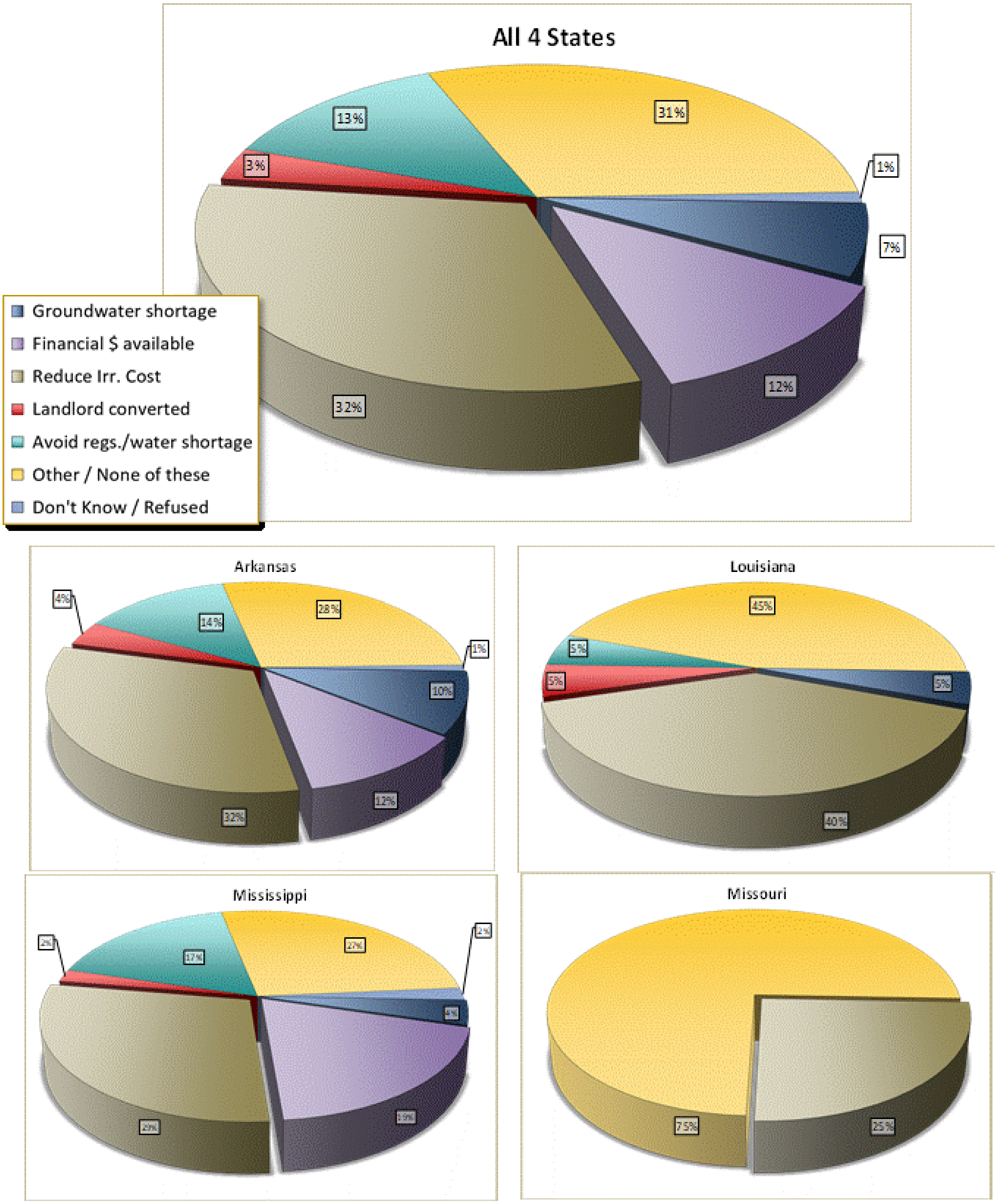


Figure 31. Pie graphs showing main reasons for adopting on-farm water storage for the 4-state region and

10.2.2 Precision Leveling

Participants were not specifically asked about adopting zero grade, however, they were asked about precision leveling. Respondents clearly indicated that the reason for precision leveling was due to improving irrigation (35%) or “making it easier” and improved profitability (33%). Mississippi irrigators associate precision leveling with an increase in profitability, much more so than the other states. About a third of all irrigators in all four states responded that they adopted precision leveling because it made irrigation easier.

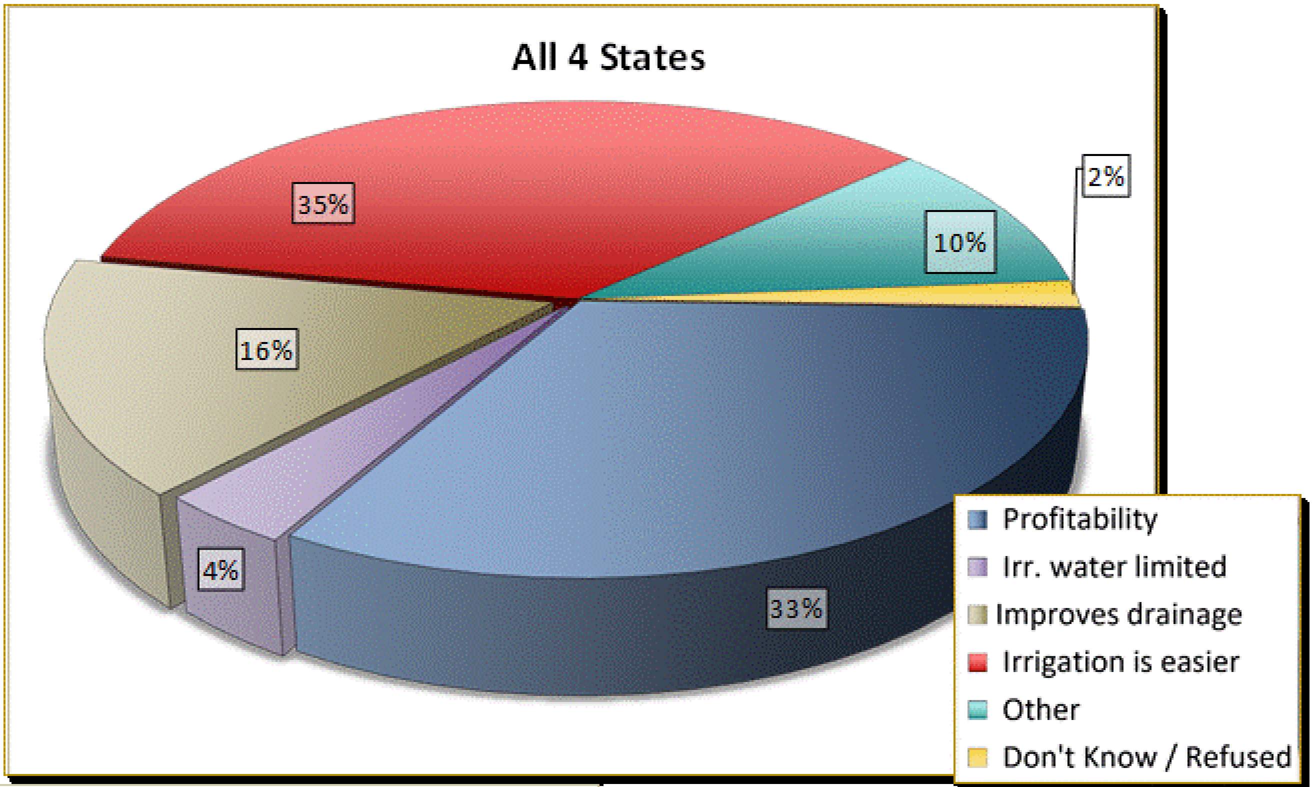
Table 53. Main reasons given for adopting precision leveling

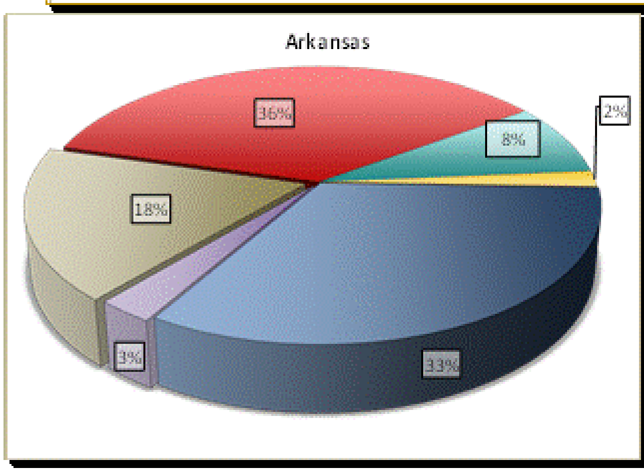
Reason for Adoption	Arkansas	Louisiana	Mississippi	Missouri	All 4 States
Profitability	33%	24%	44%	17%	33%
Irrigation water was limited	3%	4%	4%	17%	4%
It improves drainage on my farms	18%	20%	4%	17%	16%
It makes irrigation easier	36%	32%	36%	33%	35%
Other	8%	20%	8%	17%	10%
Don't Know/Refused	2%	0%	4%	0%	2%

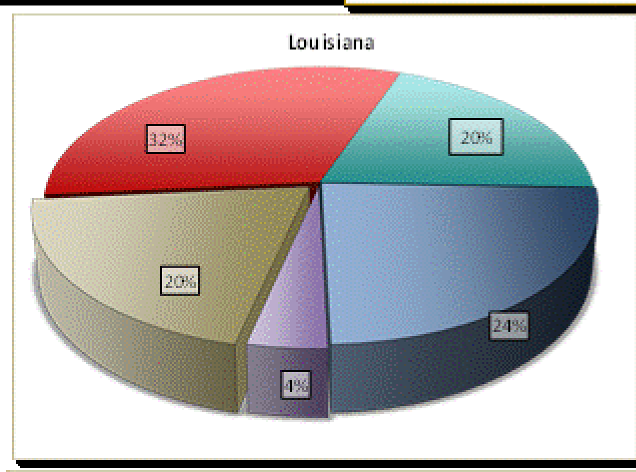
Table 54. Other reasons cited for adopting the precision leveling

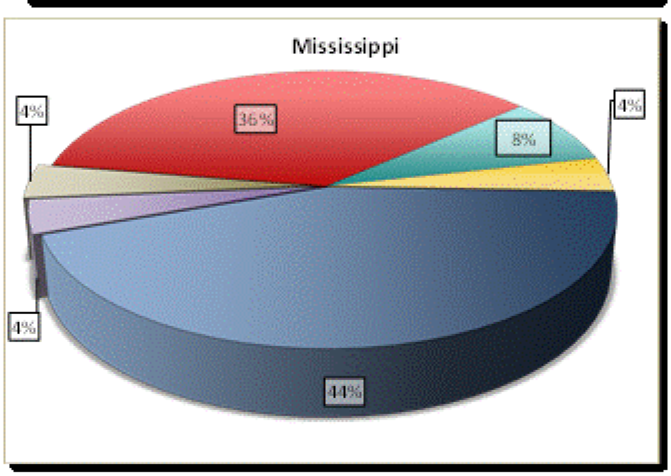
AR	LA	MS	MO
Reasons for Adopting			
• So, we didn't need to build levees • It was already there • It took out the need for levees • Landlord did it • It was already there • Increase rice acres • It was already there • It was already there • Increased efficiency	• Started moving dirt dry rather than wet • It was already there • Water conservation • Water conservation • Weed control	• Water conservation • Water conservation	• Owns a precision leveling company
Reasons for NOT Adopting			
• Likes using zero grade • No rice planted in 2015 • Did not plant crops due to flooding in 2015 • Type of ground • No rice planted in 2015 • No rice planted in 2015	• No rice planted in 2015 • No rice planted in 2015 • No rice planted in 2015	• No rice planted in 2015 • No rice planted in 2015 • No rice planted in 2015 • No rice planted in 2015 • No rice planted in 2015 • No rice planted in 2015	• No rice planted in 2015

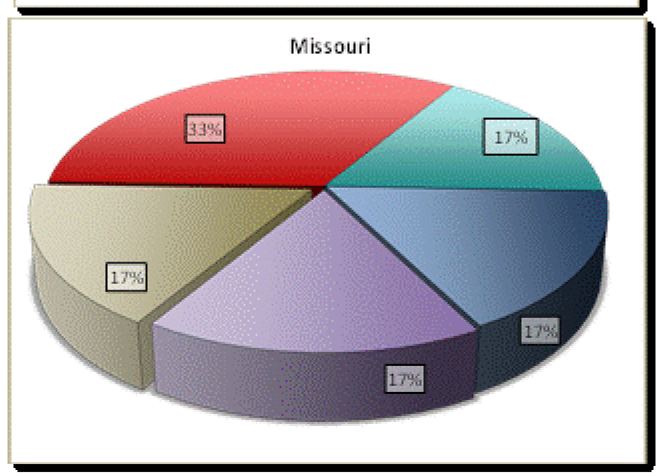
Precision Leveling











10.2.3 Computerized hole selection

About 40% of respondents indicated that they were using CHS (Q36) on their farm on a total of 244,539 acres (Q37). Respondents were asked about why they adopted (Q39) or did not adopt CHS (Q40). If Respondents indicated that they used CHS they were asked why and how many acres of CHS they had adopted. If they responded that they did not use CHS, they were asked about the reasons why.

The primary reason given for adoption CHS (**Figure 32**)was because they learned about CHS at an Extension meeting (25%). Twenty percent indicated they adopted CHS because it allowed them to reduce input costs and 20% indicated that they tried it on their farm and saw the benefit. After these reasons, industry meetings, water shortage, learning from a neighbor, an industry meeting, or the profit from it allowed in new investment and other reasons made up a mix of the last 40% of responses.

Those that responded that they did not use CHS (**Figure 33**)was mixed in either they were not interested (other category, see **Figure 34** and **Table 55**) or 16% indicated that it did not work on their farm or was not aware of CHS (14%). Thus, one can conclude that Extension driven educational efforts, self-interest in reducing input costs, and on-farm demonstrations are very effective in promoting adoption of CHS.

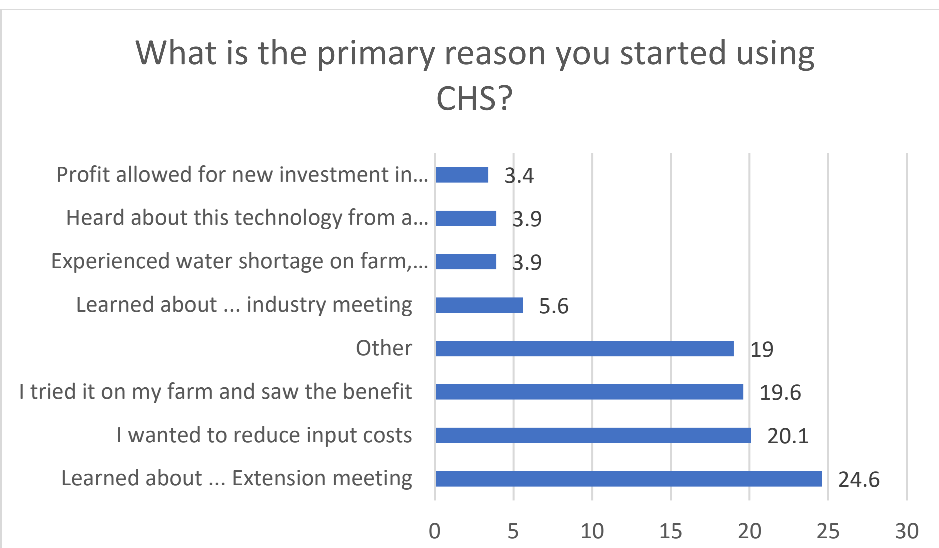


Figure 32. Primary Reasons Farmers adopt CHS

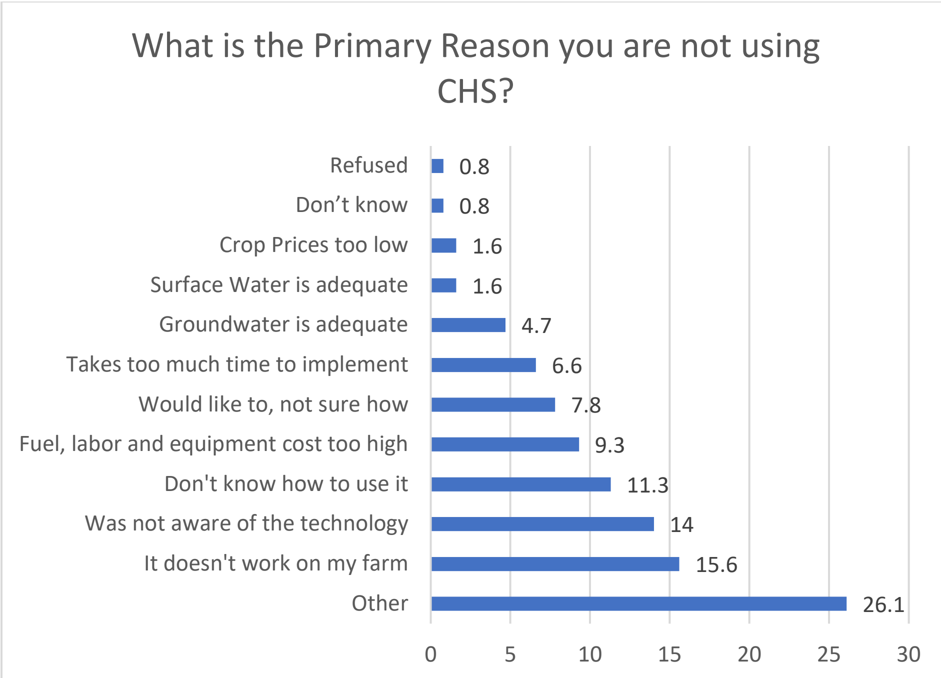


Figure 33. Primary Reasons Farmers do not adopt CHS

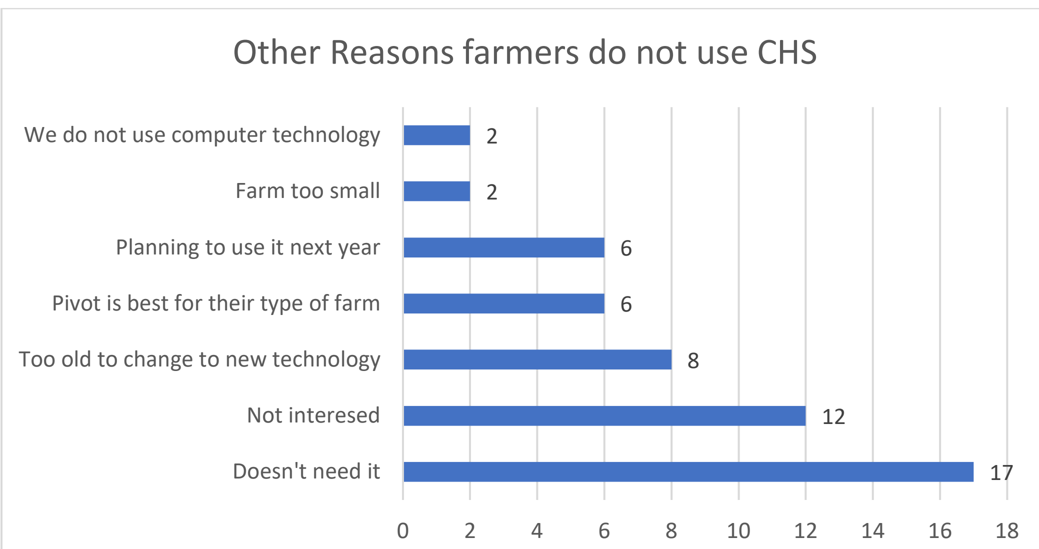


Figure 34. Other Reasons Farmers do not Adopt CHS

Table 55. Reasons provided for adopting or not adopting CHS

AR	LA	MS	MO
Reasons for Adopting			
• Water efficiency • Water conservation • Water efficiency • Reduce labor • University of Arkansas test • Had trouble with charcoal rot - because of overwatering • Overwatering the short rows from pivots • Water efficiency • Water efficiency • Fields are cornered and he has trouble getting water out	• Water efficiency • NRCS Program • For conservation practices • NRCS Program • Water efficiency • Water efficiency • Water efficiency • Save water and fuel	• Water efficiency • To save water and money • NRCS Program • For conservation practices • For conservation practices • Water efficiency. • Irrigation efficiency • Irrigation efficiency • YMD required it • NRCS Program • Water efficiency • Water efficiency • Irrigation consultant convinced me • Water efficiency	• Because of the different lengths of rows in the field • NRCS Program
Reasons for NOT Adopting			
• Pivot is best for their type of farm • Too old to change to new technology • Doesn't need it • Too old to change to new technology • Planning to use it next year • Doesn't need it • Not interested • Doesn't need it • Tried it and had problems • Doesn't need it • Too old to change to new technology • Doesn't need it • Not interested • Planning to use it next year • Doesn't need it • Planning to use it next year • Doesn't need it • Not interested • Not convenient for their farm • Doesn't need it • Not interested • No level ground at all • Not interested • Knows the soil well enough to predict hole size needed • Doesn't need it • Doesn't need it • Too old to change to new technology • Doesn't need it • It would not serve its purpose • Doesn't need it • The computer doesn't know if a PHAUCET uses more water than the others • Doesn't need it • Wells surge, cannot get accurate read to determine holes size • Doesn't need it	• better understanding of how the farm works and is satisfied with the output • We do not use computer technology • Not interested • It's not accurate • We do not use computer technology • Not interested • Conditions on where he lives. They usually have enough water. • It's a new system to the area • Not interested • Planning to use it next year	• It was not how it was set up when he got it • Planning to use it next year • Doesn't need it • Too old to change to new technology • Farm too small • Pivot is best for their type of farm • Too old to change to new technology • Not interested • Doesn't need it • Not interested • Pivot is best for their type of farm • Pivot is best for their type of farm • The land has been shot to grade	• Not interested • Too old to change to new technology • Farm too small • Pivot is best for their type of farm • Knows the size of the holes he needs on his farms • Doesn't need it • Too old to change to new technology • Not interested • Planning to use it next year • Pivot is best for their type of farm

10.2.4 Surge irrigation

About 21% of respondents indicated that they used surge flow irrigation on 31,292 acres in the region. They were then asked why they adopted (Q41) or did not adopt surge flow irrigation (Q42). If respondents indicated that they used surge flow they were asked why and how many acres of surge flow irrigation they had adopted. If they responded that they did not use surge flow irrigation, they were asked about the reasons why.

The primary reason given for adopting surge flow irrigation (**Figure** 35) was because they tried it on their farm (27%). 25% indicated something in the “other” category indicating that the predetermined responses did not represent the reason they adopted surge. The third most common response was that they learned about it at an Extension meeting (18%). Generalizing the “other” reasons and the remaining categories, could be condensed into a financial or personal incentive to reduce costs, improve profitability or water efficiency, or were in the process of evaluating. Many responded that an electric utility was providing a financial incentive, water efficiency, public incentive conservation programs, or they were trying it out on their farm. Clearly however, trying surge flow irrigation on their individual farm was the most common reason surge flow was adopted.

When the response was that they were not using surge flow irrigation, the most common response was that it didn’t work on their farm (25%) and the next most common reason was that they were not aware of the technology (21%). The remaining reasons including other responses (**Table 56**) made up the rest. Many commented that it did not work on their farm, waiting on research results, or there was uncertainty or a reason it didn’t work on their farm. Also many were simply not interested in the technology. Fuel, labor and equipment cost was given as a reason by 11% of the respondents. Given the responses considerable uncertainty seems apparent in the responses in the effectiveness of surge irrigation and is likely why it is not as well adopted as some of the other IBMP practices.

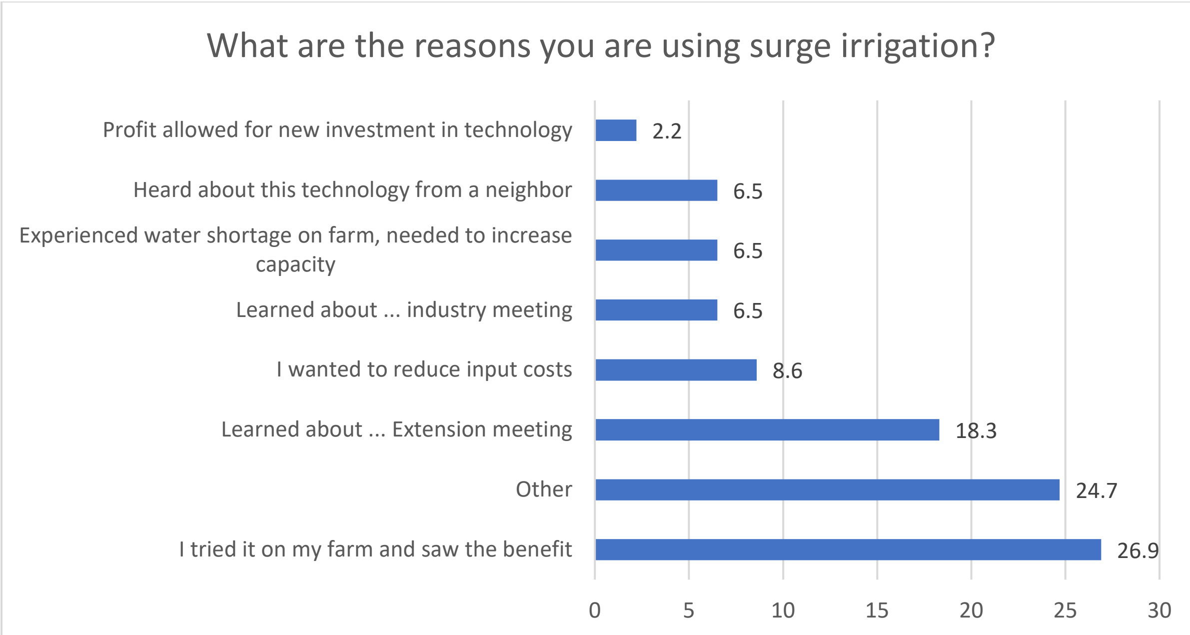


Figure 35. Reasons for adopting surge flow irrigation

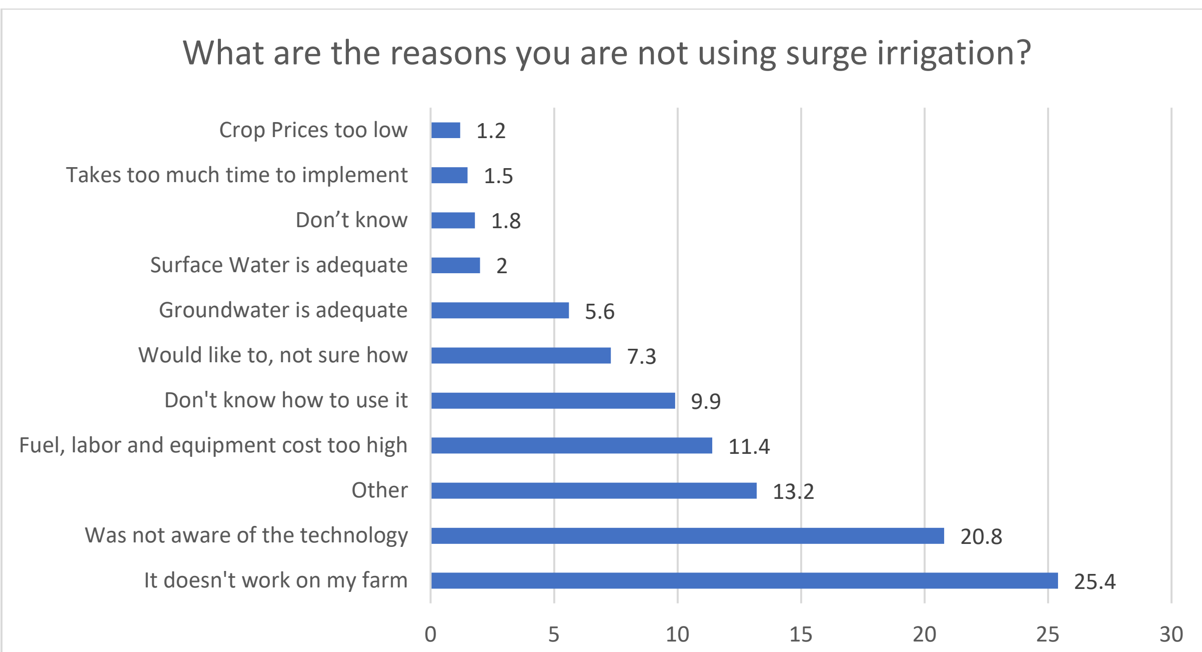


Figure 36. Reasons for not adopting surge irrigation

Table 56. Reasons provided for adopting or not adopting surge irrigation

AR	LA	MS	MO
Reasons for Adopting			
• Water efficiency • Water efficiency • Electric company offer • Water efficiency • University of Arkansas test study • Wanted to try something new • Water efficiency • Electric company offer • Electric company offer • Learned about it from soil conservation • Very high temperatures and evaporation • Reduce crop damage	• Water efficiency • NRCS Program	• NRCS Program • For conservation practices • Wanted to see if it would work • Wanted to see if it would work • Farm too small	• The government helped pay • Water efficiency • The water wasn't making it across the fields • NRCS Program
Reasons for NOT Adopting			
• Doesn't need it • If you turn it off, you lose the buildup you have • Water efficiency • Neighbors tried it in their area, and it wasn’t feasible • Waiting on research results • Waiting on research results • Doesn't need it • Heavy soils • When you shut the well, off you lose ground • Doesn't need it • Doesn't need it • In the process of trying to start surge • Furrow irrigation is sufficient • Doesn't need it • Heavy soils • Doesn't need it • In the process of trying to start surge	• Uses drip irrigation • Using other irrigation methods • never thought about trying it, use old ways • Not set up for it • Doesn't need it • No one else uses it in the area • Not interested • Not interested	• No benefit • Not interested • Present method good enough • Planning to use it next year • No benefit • Don't believe in it yet • Pivot is best for their type of farm • Present method good enough • Doesn't need it • Wells are not set up to use it • Doesn't need it • Doesn't need it • Just stopped using it • Land is not level enough	• Not interested • Pivot is best for their type of farm • Transitioning farm operation • Not interested • Not interested • Pivot is best for their type of farm

10.2.5 Multiple Inlet Rice Irrigation

Multiple Inlet Rice Irrigation can have many definitions as was discovered from this survey. It was assumed when the survey instrument was developed that MIRI meant the use of lay-flat pipe to distribute water evenly across contour and precision graded rice fields. However, respondents interpreted MIRI as this and the use of multiple inlets in a field. Another iteration of MIRI is the use of a ditch along the field to convey water to levees. However, many farmers have installed underground pipe and placed permanent outlets further down in fields, so some interpreted this to be multiple inlet, and while all of these improve the distribution of irrigation water across leveed rice fields, they are not considered as effective as using the lay-flat pipe method. Thus the intended results of obtaining adoption rates of lay-flat pipe MIRI, the reader is cautioned to understand that MIRI in these results does not always imply the lay-flat pipe method. Respondents indicated that they started using MIRI as early as 1949, with about 21% of respondents adopting the practice prior to 1986. The use of MIRI layflat pipe does not come into existence until the early 1990's with another 15% indicating adoption between 1990 and 2001. Another 24% indicated adoption between 2002 and 2006. Then adoption increases another 24% between 2007 and 2011, and between 2012 and 2015 another 18% adopt the practice. This rapid acceleration in adoption is assumed to be due to educational activities and awareness in the region. 48% of precision graded fields use MIRI and 71% of contour levee fields reported using MIRI.

For the majority that had implemented or used MIRI the most common reason for using MIRI was that they tried it on their farm and saw the benefit (35%), the second most common reason for implementing was that they wanted to reduce input costs (19%). Learning about the technology from an Extension meeting (9%), experiencing a water shortage (8%), and others reasons (7%) were less common (**Figure 37**).

When those that did not use MIRI were asked about why they did not implement MIRI (**Figure** 38), the most common response was that it did not work on their farm, presumably because they had attempted it before (33%). Groundwater was adequate was given and the second most common response (14%) and another 8% indicated that they would like to use it but were not sure how. The remainder of the reasons were widely distributed mainly around lack of awareness, interest or perception that adequate water was available or it was too labor intensive or time consuming (**Table 57**). Thus, it appears that for MIRI to be adopted, irrigators who attempt it on their farm and see the benefit are the most likely to adopt the practice.

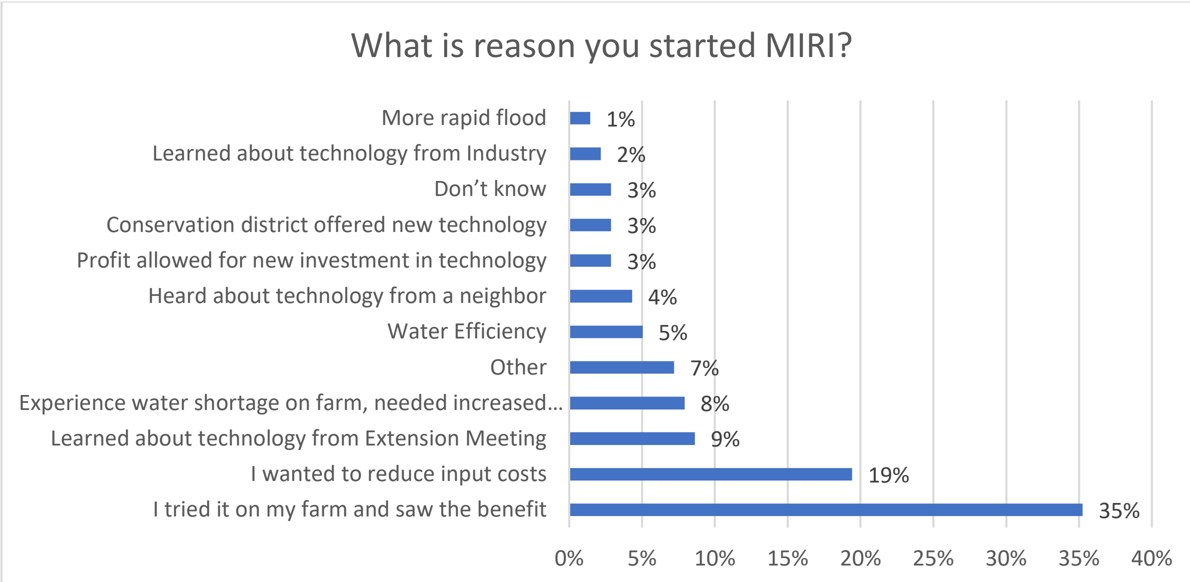


Figure 37. Reasons for adopting MIRI

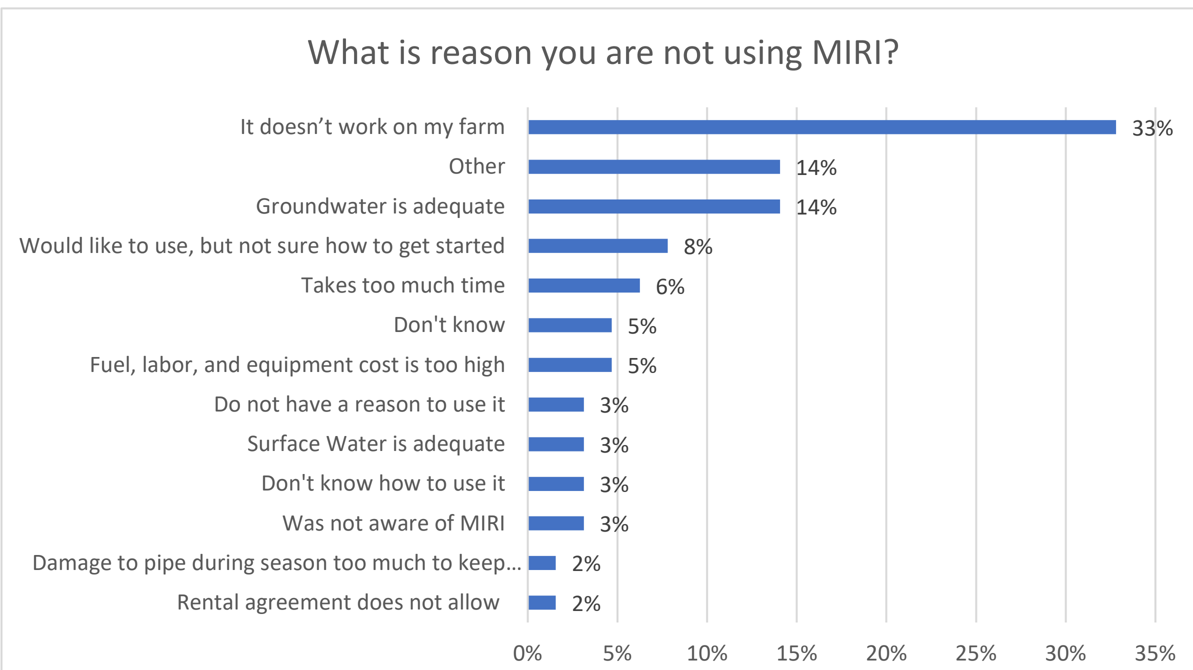


Figure 38. Reasons for not adopting MIRI

Table 57. Reasons provided for adopting or not adopting MIRI

<table>
<tr><th>MIRIAR</th><th>LA</th><th>MS</th><th>MO</th></tr>
<tr><td colspan="4">Reasons for Adopting</td></tr>
<tr><td>• Water efficiency
• Less stress on plants
• Conservation district offered new technology
• Conservation district offered new technology
• To increase water flow
• Very easy to use
• Water efficiency
• Works with the terrain
• To experiment</td><td>• Water efficiency
• Conservation district offered new technology
• More rapid flood
• It was already in place
• More rapid flood
• Put water where we needed it
• Water efficiency
• To eliminate canal systems</td><td>• Water efficiency
• Conservation district offered new technology
• Water efficiency
• Water efficiency</td><td>• Minimize cold water
• Not enough wells</td></tr>
<tr><td colspan="4">Reasons for NOT Adopting</td></tr>
<tr><td>• Don't know why anyone who uses it
• Plenty of water from river
• I have enough water
• It easier to use a single outlet
• Just not interested
• Do not have a reason to use it
• Moving towards zeros</td><td>• Very few acres of rice
• Don't plant rice very often</td><td>• Do not have a reason to use it
• Because it is zero grade</td><td>---
---</td></tr>
</table>

10.2.6 Summary of reasons for IBMP adoption

An underlying theme across the IBMP practices was that when farmers attempt IBMP practices on their farm and see the benefit this is the primary reason or motivation for adopting a new practice. Additionally, in the case of CHS and Surge irrigation learning about the practice at and Extension meeting was also a commonly expressed reason for adopting and implementing a practice. It is likely the two are more common, in that many farmers likely learn about new practices at Extension meeting and later try the practice on their farm as a demonstration working with their county Extension agent. In the case of MIRI especially, the reason for not adopting MIRI was that they tried it on their farm and it did not work. MIRI in particular can be a difficult practice to adopt at first, because how levees are blocked, pipe is installed, flows and gate setting are first implemented can be overwhelming for a farmer who has never tried it before. As such one on one assistance to help farmers and awareness and training by Extension with these practices have had a major impact in the region with the adoption of IBMPs.

11 Energy

In the *USBIS* a reason frequently provided by respondents on why they involved themselves in various practices centered on the desire to reduce operating costs. Following the millennium, later accentuated by Hurricane Katrina in 2005, energy costs began escalating. On-farm energy expenditures in the mid-South include, among other things, the cost of operating machinery, drying, heating/cooling, hauling, and the cost for pumping irrigation water. The cost of the latter expenditure can represent a quarter to a half of all energy expenditures (Reinbott, 2018).

11.1 Pumps and Energy Sources

It turns out that information on the number of pumps owned by irrigators could also be garnered in another separate way. First, as mentioned above (c.f., **9.3-Irrigated Area per Pump**), the simple question, ***Q69***, asked regarding the number of irrigation pumps --the specific type of energy source not queried about. Then later, the question series of ***Q75_1 … Q75_6*** (see below) with the accompanying six questions, ***Q76*** to ***Q81*** (an example of one of them seen below), sought more specificity in order to quantify pumping units based on the energy source. **Figure 39** shows the results of plotting the two pump ownership sources (***Q69*** and [∑***Q76*** … ***Q81***)]) against each other. The outlier points indicate pairs of data that differed from each other; this occurred about 12% of the time.

What energy sources do you use on your farm for your pumps? [Check all that apply]

Q75_1 Electric ______
Yes (-1)
No (-2)
Not sure (-3)
Refused (-4)
Q75_2 Diesel ______
Yes (-1)
No (-2)
Not sure (-3)
Refused (-4)
Q75_3 Propane ______
Yes (-1)
No (-2)
Not sure (-3)
Refused (-4)
Q75_4 Natural Gas ______
Yes (-1)
No (-2)
Not sure (-3)
Refused (-4)
Q75_5 Dual fuel ______
Yes (-1)
No (-2)
Not sure (-3)
Refused (-4)
Q75_6 Some Other Energy Source ______ (Please specify) _______
Yes (-1)
No (-2)
Not sure (-3)
Refused (-4

Q76
How many pumps use electric power? ______

Don't Know (1)
Refused (2)

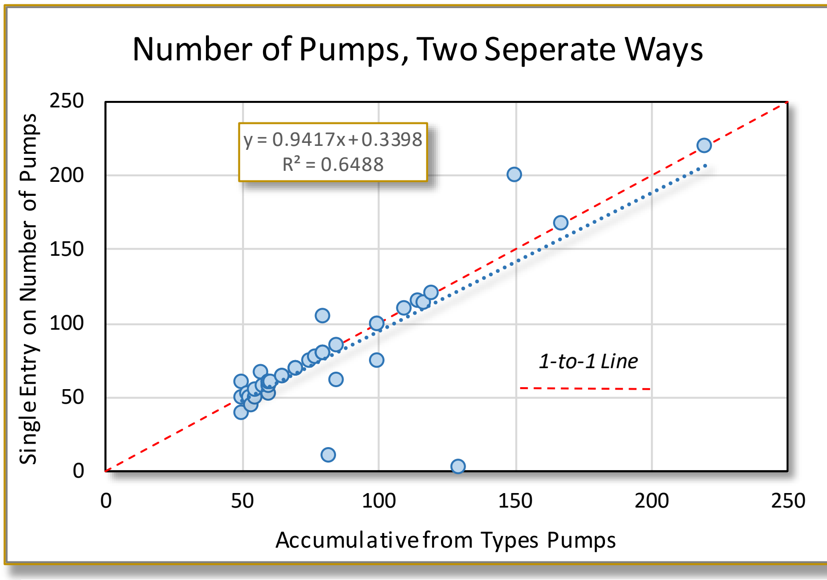


Figure 39. Number of participants' pumps derived from two separate sources

Also, it was possible to corroborate presented pump numbers from two subsequent questions, one regarding the number of pumps with permanent flow meters (***Q73***) and another regarding those having timers (***Q71***). The number of pumps indicated in both of those questions should be less than the numbers previously provided in ***Q69*** and ***Q75***. Finally, reliability on presented pump numbers can be derived and born out from the information regarding individuals' presented acreage divided by the amount of expected serviced area per pump (discussed in ***9.3.1***); typically there was a pump for every 120 irrigated acres.

11.1.1 Sources of Energy Used in Pumping

Question series ***Q75_1*** … ***Q75_6*** with follow up questions ***Q76*** … ***Q81*** were used to query the mid-South irrigators on the energy sources used for pumping water are seen below.

Q76
How many pumps use electric power? ______

Don't Know (1)
Refused (2)

Electricity-driven pumps are widely used for irrigation in the mid-South, where five out of every six farms (83%) employed at least one electric pump (TABLE p 103).

Locale	Respondents indicating power source of pumps	NO Electric Motors in use		SOME Electric Motors in use	
		(N)	(%)	(N)	(%)
Arkansas	191	27	14%	164	85%
Louisiana	88	17	19%	71	79%
Mississippi	142	20	14%	122	88%
Missouri	21	8	33%	13	54%
All 4 States	442	72	16%	370	83%

11.2 Projected Energy Savings

USB survey results agreed with local farm media's claims on a decrease in energy use when employing zero-grade. In fact, in the USB study, zero-grade was the top IBMP in terms of energy savings engendered (Table 4). On average, interviewees felt it had resulted in a 22.6% reduction in energy use/cost. However, over half the time (53.3%) survey respondents indicated no energy savings on the IBMPs they were rating. The IBMP having the most zero energy reduction scores was the adoption center pivot at 79%. Zero-grade had the lowest percent of all practices in tallying zero energy reduction scores (25%).

Becoming efficient in using an IBMP may well be a learned trait. For example, on average, it was thought that using tail water recovery systems only reduced energy by 14%, but at the same time managing to have the survey's highest score on perceived energy reduction (90%). The mean values in Table 4 may reflect a skewing of results due to inexperience with the practice in question that could improve over time. Therefore, the table also includes the maximum and 90%- & 80%-percentile values that might represent possible savings for savvy practitioners once they had fully climbed the learning curve.

Table 58. Estimated energy savings from nine IBMPs in the mid-South, showing mean and number. Also shown are higher-end potentials (maximum & 90%- and 80%-percentiles) and percent of sample reporting ZERO energy reduction.

Practice	$\bar{X}$	N	Higher Potentials			% saying ZERO energy reduction
			Max	Percentile		
				90%-P	80%-P	
Zero Grade	23%	51	65%	50%	35%	25%
Tail water recovery	14%	119	90%	40%	25%	45%
Storage Reservoir	14%	100	75%	50%	25%	54%
Multi Inlet	13%	181	75%	30%	25%	45%
Scheduling	13%	95	50%	30%	25%	35%
Surge	11%	74	50%	30%	20%	47%
End Blocking	10%	90	50%	21%	15%	38%
Deep Tillage	6%	194	50%	25%	15%	69%
Center Pivot	4%	151	45%	20%	5%	79%
All	10.8%	1,055	---	---	---	53.3%

11.3 Timers

The presence of timers on pumping units can be both an energy- and labor-saving device.

Two logical trends in timer usage were found within the data. These were that:

- Timer usage increases with the presence of center pivot irrigation.
- Timer usage increases if the pumping plant is electric.

This first relationship is logical in that, very often, a pivot is programmed to turn off (and sometimes to commence operation) at certain specific key input parameters, such as the pivot's compass direction. Since the pivot, in effect, has time-related instructions, the pumping unit does also. **Figure 40** shows the percentage of timer use versus the percentage of the farm irrigated under pivots in the four broad categories of: 0% of the farm, 1 to 33% of the farm, 34 to 67% of the farm, and 68 to 100% of the farm is irrigated using pivots. When the participant had no pivots at all then, on average, 47% of their pumping units had timers. This value increased to 70% for participants with 68 to 100% of their land in pivots.

Overall, 42% of farmers in the mid-South had some amount of pivot irrigation; for those having a pivot, this proportion varied from 2% to 100% of their total irrigated acreage. In both Missouri and Mississippi, the portion of irrigators who had at least some amount of pivot ground was larger than those with no pivot land what so ever (**Table 59**).

Table 59. Percentage of farmers who USE / DO NOT USE pivots

Location	NO Pivots used (%)	At least SOME Pivots used (%)
Arkansas	68%	32%
Louisiana	72%	28%
Mississippi	40%	60%
Missouri	29%	71%
All 4 States	58%	42%

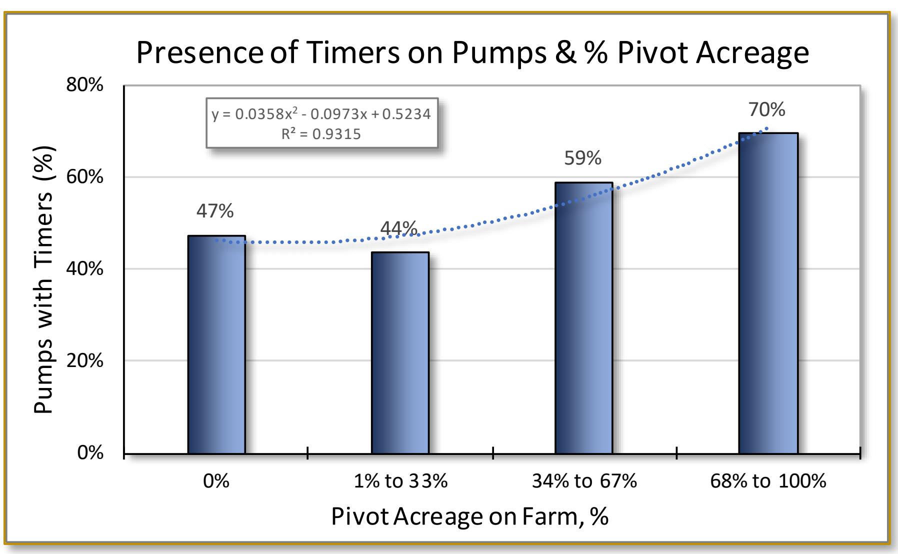


Figure 40. Timer use relative to % of farm irrigated by pivots.

The other relationship that was observed regarding timers was that farms having higher percentages of electrical drive units were more likely to be using timers. Note that a surprisingly large percentage of growers (83%) had at least one electric pump (**Table 60**). It seems intuitive that since ON/OFF relays are inexpensive and easy to use compared to a something like a Murphy switch required for combustible engines, timers will be more frequently installed on electric units. The percent number of electric units amongst all the power unit components in the farms is shown graphed against pumps with timers in a bar graph comprised of 10% increments (**Figure 41**).

Table 60 Percentage of farmers having at least one electric pump & those have none.

Location	NO Electric Pumps used (%)	At least SOME Electric Pumps used (%)
Arkansas	14%	85%
Louisiana	19%	79%
Mississippi	14%	88%
Missouri	33%	54%
All 4 States	16%	83%

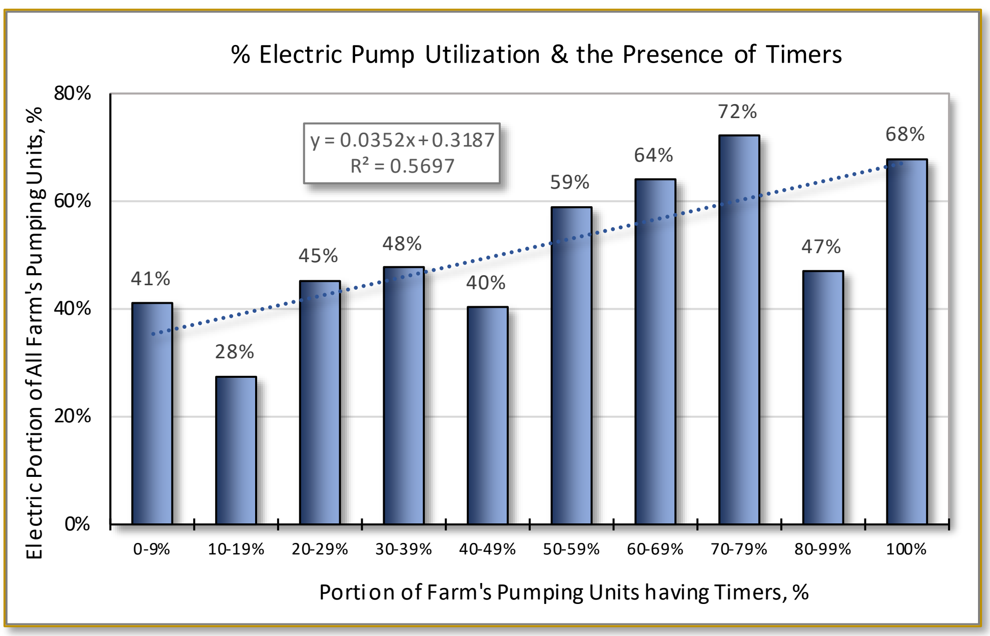


Figure 41. Timer use relative to % of pumping units that are electric.

11.4 Water Meters

There are a variety of benefits that can be derived from measuring irrigation water flow. These include output monitoring (e.g., is my pump/well sustaining its original flowrate?), ability to determine energy consumption of pump by efficiency testing, irrigation scheduling (e.g., am I supplying the quantity of water that is needed by my crops?), and documenting water withdraw rights.

On the negative side, cost is always involved with water measurement. For some, information concerning the amount of water being pumped is considered a private matter and, once it has been quantified, could get into the hands of others.

Several questions regarding water meters were asked of the participants. First, a general interrogatory, Question ***Q72***, asked if the participant owned any flow meters (see below); 95.7% of the participants responded. Then two follow up questions (***Q73*** and ***Q74***) inquired on the number of permanent-in-place and portable meters that were owned.

Q72

Do you own any flow meters?

- ʘ Yes (1)
- ʘ No (2)
- ʘ Prefer not to answer (3)

Q73

How many of these flow meters are mounted permanently? ______

Don't Know (1)
Refused (2)

Q74

How many portable flow meters do you own? ______

Don't Know (1)
Refused (2)

Over four fifths (42.4%) of the growers indicated that they had a flow meter; however, differences by state ranged greatly, with Missouri, the least, having 0.0% and Mississippi, the highest, having 70.5% (**Table 61**).

Table 61. Percentage of irrigators with either in-place or portable water meters by state

Location	Yes	No	No Answer
Arkansas	37.5%	62.5%	3.5%
Louisiana	16.1%	83.9%	6.5%
Mississippi	70.5%	29.5%	1.4%
Missouri	0.0%	100.0%	19.2%
All 4 States	42.4%	57.6%	4.3%

In every case, for each of the four crops where yield data had been collected, yields were higher for those irrigators who had a water meter (**Table 62** and **Figure 42**). Whether this yield increase was an artifice of metering leading growers to better yields, or just to the fact that better managers simply owned meters is not known. The average relative yield increase was 6.9%.[20]

Table 62. Average 2015 yields between irrigators with a water meter and those not having one for four crops.

Region	Corn				Soybean			
	All Units	Meter?		Δ in Yield	All Units	Meter?		Δ in Yield
		YES	NO			YES	NO	
	Bushels per acre				Bushels per acre			
Arkansas	188.1 (106)	194.4 (44)	188.8 (56)	5.7	55.7 (180)	59.3 (67)	53.5 (107)	5.7
Louisiana	178.5 (48)	173.6 (11)	178.1 (33)	-4.5	64.4 (54)	63.4 (11)	64.9 (38)	-1.6
Mississippi	188.3 (87)	191.2 (68)	176.4 (18)	14.8	57.7 (123)	59.1 (91)	53.6 (30)	5.5
All 3 States	202.8 (241)	190.8 (123)	183.5 (107)	4.3	57.8 (357)	59.4 (169)	56.2 (175)	3.2

Region	Rice				Cotton			
	All Units	Meter?		Δ in Yield	All Units	Meter?		Δ in Yield
		YES	NO			YES	NO	
	Bushels per acre				Pounds per acre			
Arkansas	179.2 (134)	188.1 (54)	173.9 (76)	14.1	1,258.3 (27)	1,287.0 (10)	1,241.5 (17)	45.5
Louisiana	168.6 (23)	173.8 (4)	167.4 (18)	6.4	1,157.1 (14)	1,333.3 (3)	1,025.0 (8)	308.3
Mississippi	178.9 (30)	179.9 (25)	174.0 (5)	5.9	1,260.0 (40)	1,288.7 (31)	1,161.1 (9)	127.6
All 3 States	177.8 (187)	184.9 (83)	173.2 (99)	11.7	1,234.2 (81)	1,291.4 (44)	1,184.6 (34)	106.7

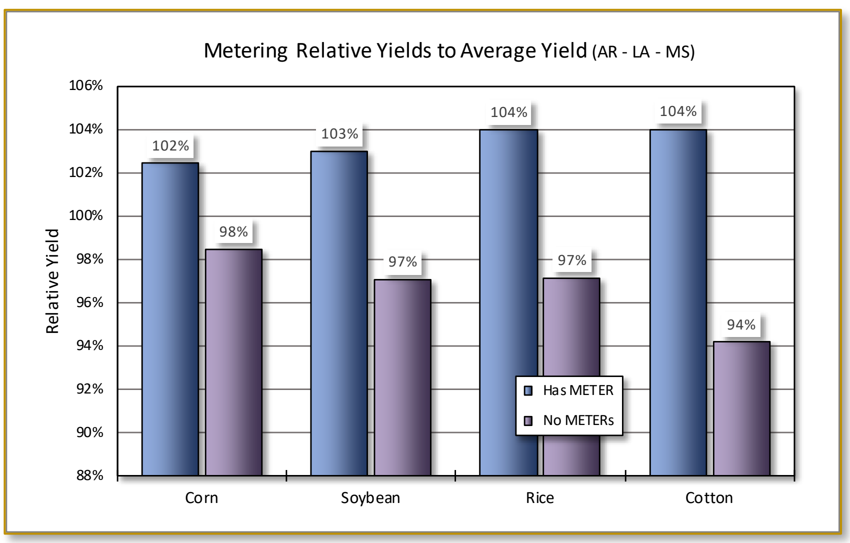


Figure 42. The relative yields for metering and not metering based on the average reported crop yield.

[20] Since Missouri had no water meters, just Arkansas, Louisiana and Mississippi data were used to calculate reference yield differences between metering and not metering.

11.4.1 An Influencing Factor on Water Meters:

On a per farm basis, Mississippi had approximately twice and then again four times as many farm owners with a flow metering device (either permanently mounted or portable) then did Louisiana or Arkansas, respectively. Missouri had no irrigators using flow meters.

The reason that so many irrigators in Mississippi may be utilizing water meters could be due the Yazoo Mississippi Delta Joint Water Management District's (YMD) Voluntary Metering Program. This program (Table **63** and **Figure 43**) encourages its approximately 1,700 members to install meters on at list 10% of their irrigation wells. The average state meter use is 71%, but with 19 YMD counties the average becomes 78% (and it should be noted that the land area of almost half of the YMD counties only partially lies within the district boundaries).

Table 63. Percentage of irrigators with any type of flowmeter by state; MS data is broken down as being within YMD boundaries or not

Location	Has Flow Meter? YES	Has Flow Meter? NO	Total Flow Meter	% Flow Meter? YES	%Flow Meter? NO
Arkansas	72	120	192	38%	63%
Louisiana	14	73	87	16%	84%
Mississippi	103	43	146	71%	29%
Mississippi - YMD	99	28	127	78%	22%
Mississippi – non-YMD	4	15	19	21%	79%
Missouri	0	21	21	0%	100%
All 4 States	189	257	446	42%	58%

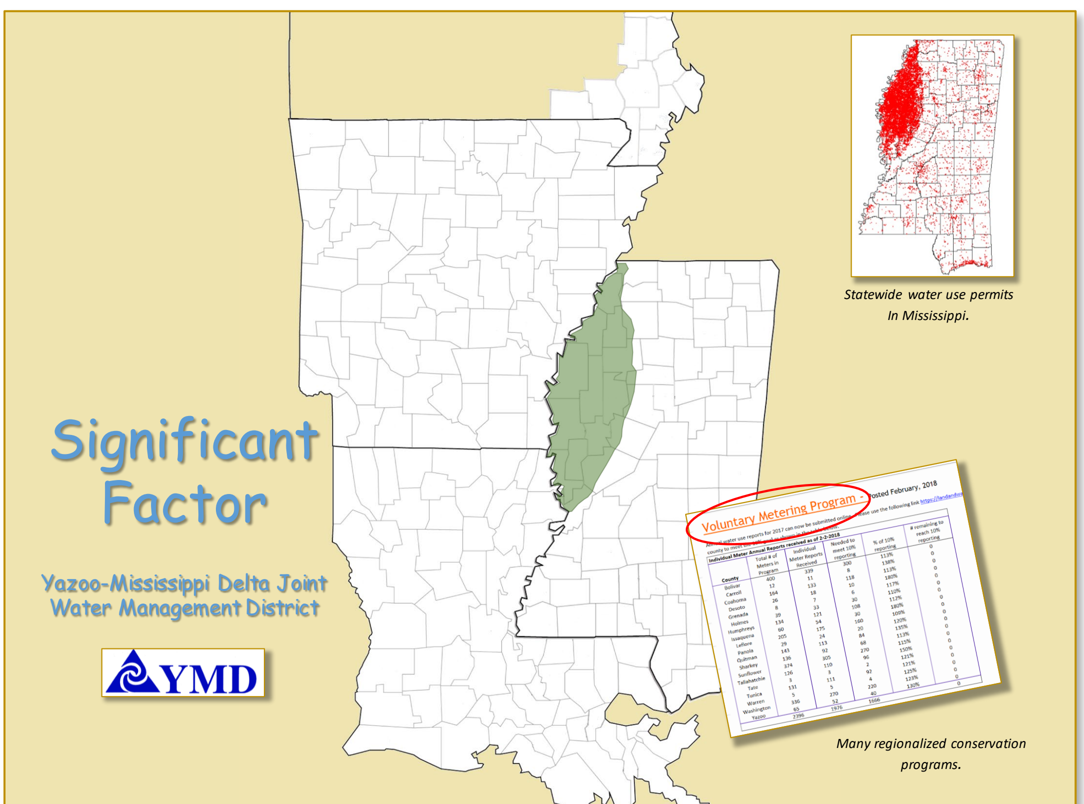


Figure 43. The region of the Yazoo Mississippi Delta Joint Water Management District (YMD) shown within mid-South map. The density of irrigation wells in the YMD shown in the inset map of Mississippi & a YMD datasheet on their *Voluntary Metering Program*.

The map of the counties within the mid-South region indicating the county's average percentage of users employing some form of water metering is seen in **Figure 44**. The figure also delineates the boundary limits of the YMD. The cooler blue colors indicate higher levels of meter use (70 – 100%) and, as shown, are predominant within the YMD area.

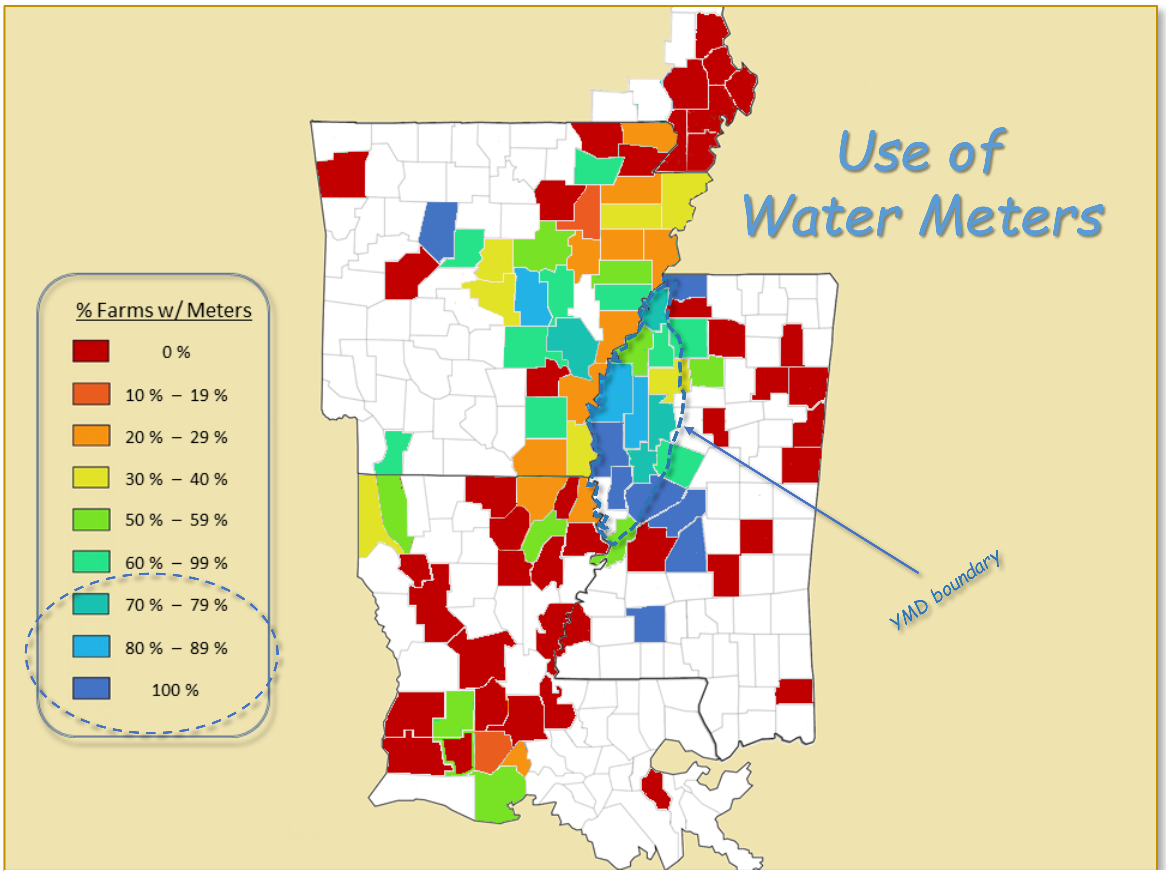


Figure 44 Percentage of water meter use in counties.

The work that the YMD has done and its impact on producers regarding the adoption of water measurement as an ***IBMP*** is witnessed in **Figure 44**.

Soon, components from the YMD Voluntary Metering Program will be incorporated into a federal research program that will greatly expand the knowledge on the characteristics of the Mississippi River Valley Alluvial Aquifer from Cape Girardeau, Mo. down to Natchez, Miss. Low altitude flights from a specially equipped helicopter capable of reading electromagnetic field and radio waves down through the surface will crisscross the area. This trove of mega-data will be used to accurately model the aquifer.

Another YMD program of great importance to irrigators throughout the mid-South is their intensive multi-year, on-farm water use study on hundreds of irrigated fields. Data is collected on various crops and types (as well as sub-types) of irrigation systems documenting water use.

One of the main takeaways from this *USBIP* study is the suggestion that soybean commodity groups in the mid-South increase their partnership activities with the YMD, in such things as educational meetings, joint publications, etc. have likely enhanced irrigator acceptance and utilization of meters and as shown above the profitability of those irrigators.

12 Conservation Practices

12.1 Storage Reservoirs

At 47%, Arkansas leads all the other states in the use of on-farm water storage reservoirs per farm (***WSR***s) (**Figure 45**). In the case of Arkansas, those farms with ***WSR***s, have, on average, 2.20 of them. Also, in Arkansas, ***WSR***s are strongly associated with rice growing, where 88% of rice growers had at least one WSR unit. ***WSR***s, generally associate with surface irrigation, were found in each state, but, as mentioned, more notably in AR (90) and MS (42) as shown in **Table 64**. Although farms that grew rice were less than 20% of the total farms, these rice farms had an inordinate number of these ***WSR***s – 67.3% on a farm basis and 73.5% on an areal basis. Arkansas, by far, had the highest ***WSR***s use, both in reported numbers and area serviced. In AR, the rice farms were replete with ***WSR***s, whereas, farms not growing rice did not make near as much use of them.

Table 64 includes other information regarding Arkansas and the three other states. Occasionally, when present on a farm, the ***WSR***, would service the owner's full acreage, but on average just 22% of the owners total irrigated land was wedded to a with ***WSR*** (**Table 65**).

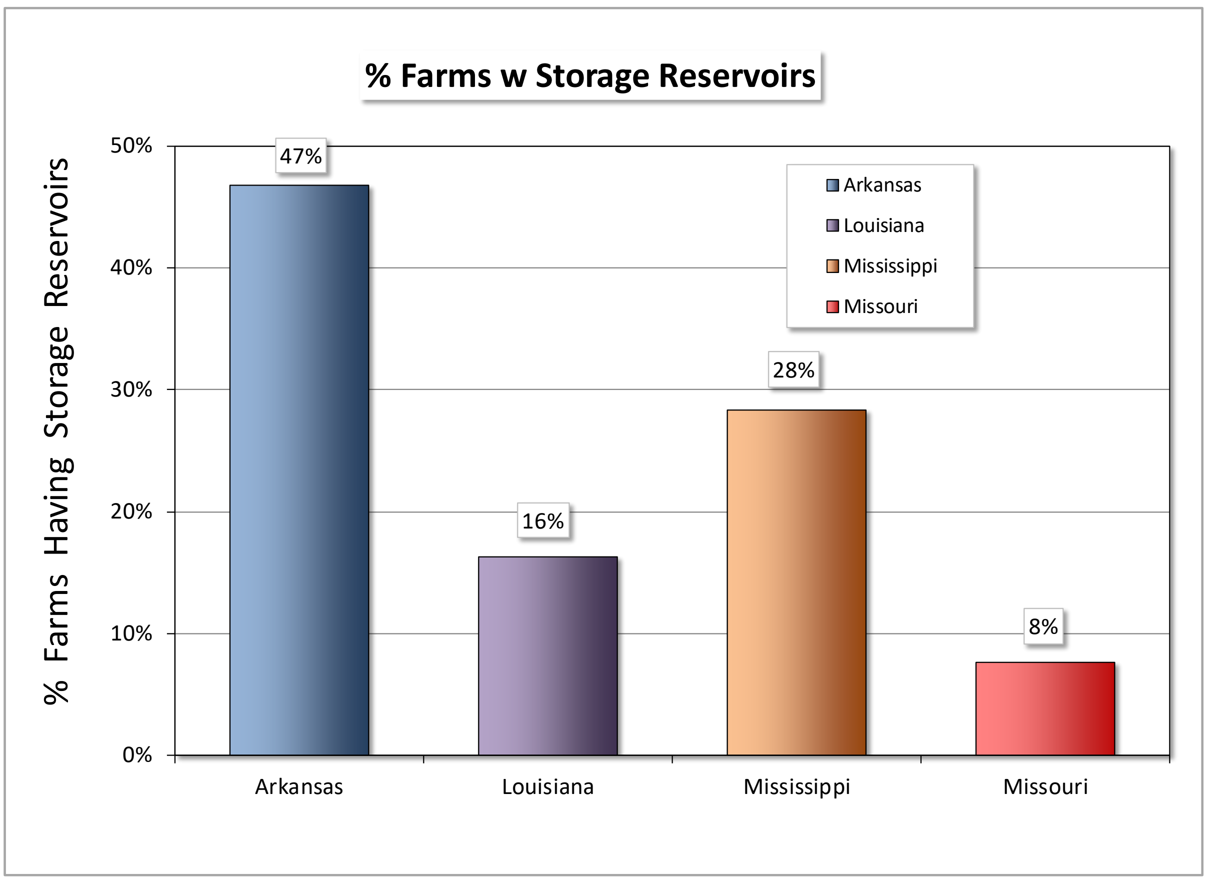


Figure 45. Percent of irrigation farms having some amount of storage reservoirs

Table 64. In AR, LA, MS, and MO, the Number and Total Farm Acreage for All Farms with Tailwater Systems (TWSs), plus Same Data for Farms NOT Growing Rice that have TWSs; the relative Percentage of Rice-Growing Farms to All Farms is also shown.

STATE	Number of Farms Having TWSs (All Farms)	Number of Farms Having TWSs, but do NOT Grow Rice	Proportion of TWSs Found on Rice-Growing Farms	Acreage of Farms Having TWSs (All Farms)	Acreage of Farms Having TWSs, but do NOT Grow Rice	Proportion of TWSs Found on Rice Farms
			%	Acres	Acres	%
Arkansas	90	11	87.8	65,906	8,945	86.4
Louisiana	13	8	38.5	16,350	11,050	32.4
Mississippi	42	28	33.3	15,372	5,822	62.1
Missouri	2	1	50.0	90	50	44.4
All 4 States	147	48	67.3	97,718	25,867	73.5

Table 65. Area serviced with Storage Reservoirs (avg., s.d., sum, min & max), SRs per farm, and avg. farm size & portion of it serviced with SRs

Region	Serviced with Storage Reservoirs					SRs / farm		Average Farm Size (% of it serviced SRs)
	Average Area (acres) (n)	St. Dev. (acres)	Sum Area (acres)	Min (acres)	Max (acres)	Farms w SRs	All farms	
Arkansas	732.3 (90)	905.6	65,906	50	6,000	2.20	0.82	3,587 (25 %)
Louisiana	1,257.7 (13)	910.7	16,350	200	3,000	2.08	0.27	2,311 (31%)
Mississippi	366.0 (42)	820.8	15,372	4	1,500	1.98	0.55	2,591 (15 %)
Missouri	45.0 (2)	820.9	90	40	50	2.67	0.31	3,339 (4 %)
All 4 States	664.7 (147)	816.9	97,718	4	6,000	2.13	0.60	3,042 (22 %)

An example of this line of questioning is seen with questions ***Q17*** (Do you have a tailwater recovery system [***TWR***]?) followed by ***Q25*** (What is the primary reason you started using a ***TWR*** …?). In regards having a ***TWR***, 152 responded YES. Of the five "canned" reasons provided, the one involving the desire to reduce irrigation costs –nearly half the group chose it-- was the most popular. However, 42% of the respondents had chosen OTHER, and all 126 in this group elaborated on the reason. Items mentioned included salinity problems, desiring to use warmer water, etc.

Six of the OTHER responses mentioned water quality or salinity. Five of the locales were in Arkansas: Cross, Chicot (2), Arkansas, and Green counties, located on the Mississippi River or one county away from it. The other salinity response came from Morehouse Parish, LA.

Q17 Do you have a tailwater recovery system? ▯ Yes (1) ▯ No (2) ▯ Prefer not to answer (3)

Q18 How many irrigated acres use tailwater recovery? ______ Don't Know (-1) Refused (-2)

When did you start using a tailwater recovery system? Q19_1 Year Q19_2 Month

Q20 How many storage reservoirs do you have? ______ Don't Know (-1) Refused (-2)

13 Methods of Farming

13.1 Crop Mix

The prime crops of focus were corn, cotton, soybeans and rice; for these four crops inquiries were made both regarding acres and yield level. For two other crops, peanuts and grain sorghum, information was collected only on acres. Additionally, sporadic information involving other crops (e.g., sunflowers, sod, etc.) was mentioned, but not tabulated.

Interestingly, following the ***Q03*** question series establishing data on the six irrigated crops of interest, grown, question ***Q04*** poses: *"Do you have any additional acres, either fallowed or not accounted for by the crops we've discussed?"* Nearly a third of those surveyed (31%) replied that they did.

Figure 46 displays the average acre amount for these six crops when they are present on mid-South farms. The figure does not reflect what is the average acreage amount using all 466 survey farms, since the on-farm presence of the various crops varied from a low of 2% (peanuts) to a high of 84% (soybeans); these crop participation percentages are seen as cutouts on the figure. **Figure 47** is composed of two over-under charts: top (a pie-chart version of **Figure 46**) illustrates average farmer-owned acreage for the six irrigated crops in the mid-South when present. The bottom, also in pie-chart form, reflects mean size when average over all 466 farms in the survey. They are displayed next to each other for the sake of comparison.

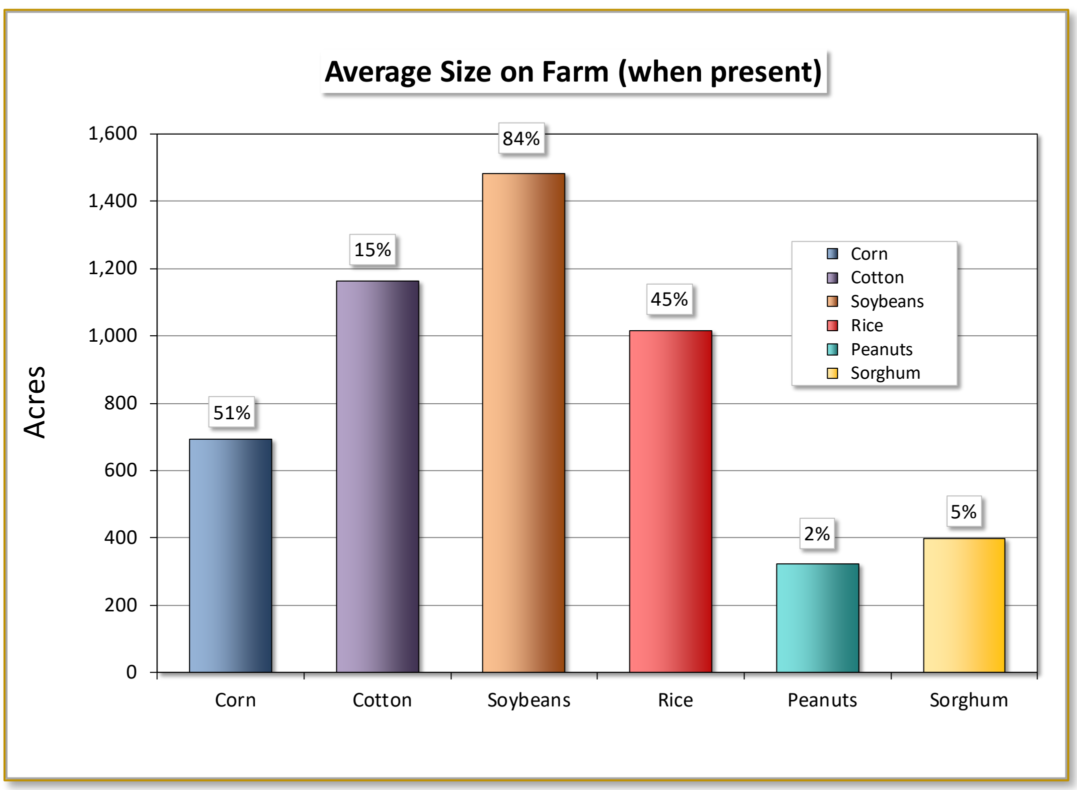
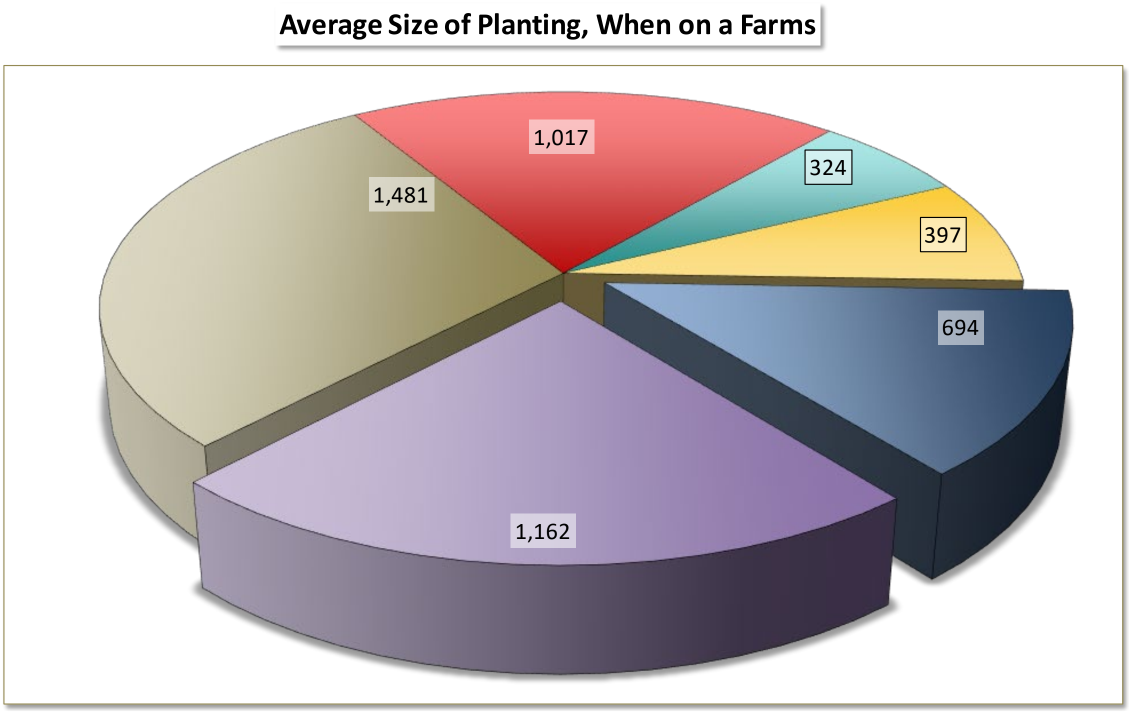


Figure 46. Average size of acreage of various irrigated crops when present. On farm Cutout above bars is the % of farms the crop was found in



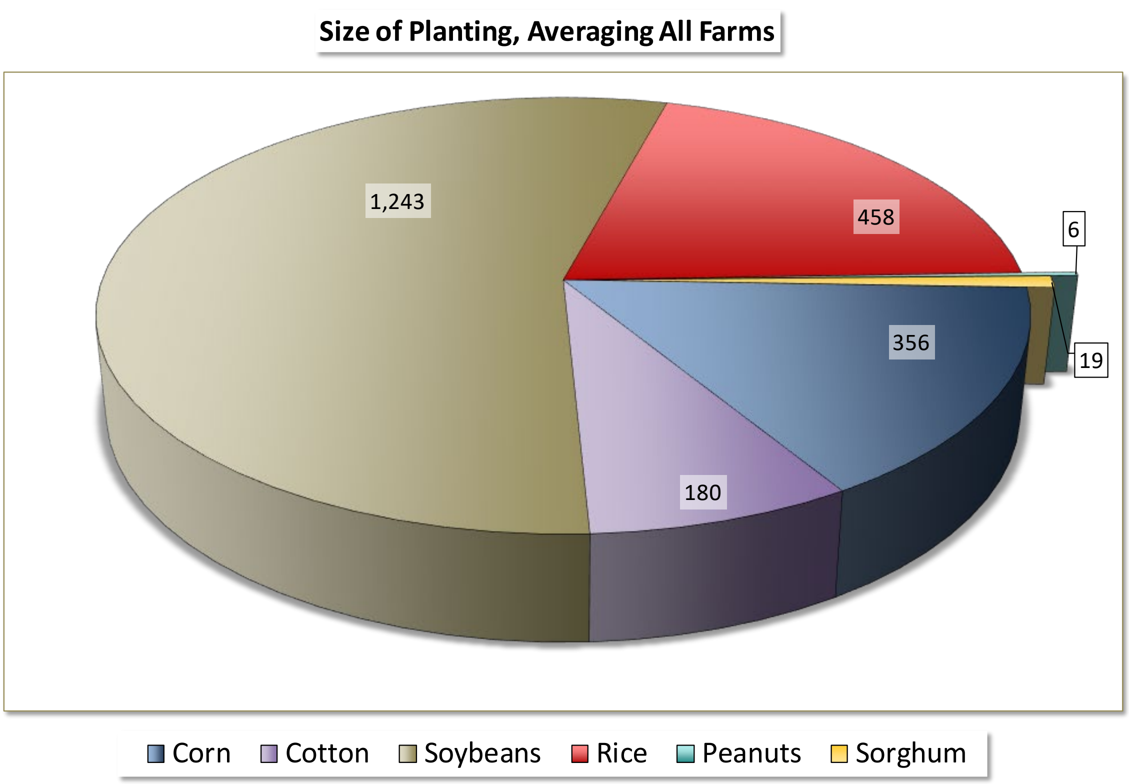


Figure 47. Pie charts illustrating portions in acres for six irrigated crops in the mid-South. Bottom: average size over all 466 farms in the survey. Top: average size based on only farms having that crop

Table 66. Total Acreage, maximum and minimum values in the sample, mean size and its standard deviation and number by crop and state.

Arkansas							
Crop →	Corn	Cotton	Soybeans	Rice	Peanuts	Grain Sorghum	TOTAL CROPS
Total	48,143	22,250	268,971	145,873	1,615	6,480	493,332
Mean	529.0	967.4	1,453.9	1,072.6	323.0	432.0	1,084.2
n	91	23	185	136	5	15	455
Std. Dev.	483.4	780.1	1,512.9	1,046.1	211.3	413.0	---
Min	30	50	40	18	15	20	15
Max	2,000	3,000	12,000	6,250	500	1,500	12,000
Louisiana							
Crop →	Corn	Cotton	Soybeans	Rice	Peanuts	Grain Sorghum	TOTAL CROPS
Total	34,030	9,589	62,765	32,090	80	662	139,216
Mean	872.6	958.9	1,255.3	916.9	80.0	220.7	1,008.8
n	39	10	50	35	1	3	138
Std. Dev.	824.1	679.2	2,264.8	734.3	---	251.6	---
Min	5	50	52	24	80	12	5
Max	3,400	2,000	15,000	3,000	80	500	15,000
Mississippi							
Crop →	Corn	Cotton	Soybeans	Rice	Peanuts	Grain Sorghum	TOTAL CROPS
Total	60,965	36,350	202,298	25,805	900	1,300	327,618
Mean	752.7	1,211.7	1,658.2	921.6	450.0	433.3	1,231.6
n	81	30	122	28	2	3	266
Std. Dev.	834.5	1,351.0	1,730.2	1,006.3	565.7	57.7	---
Min	5	45	67	80	50	400	5
Max	4,500	7,000	9,400	3,850	850	500	9,400
Missouri							
Crop →	Corn	Cotton	Soybeans	Rice	Peanuts	Grain Sorghum	TOTAL CROPS
Total	17,982	13,150	28,915	3,600	0	300	63,947
Mean	856.3	1,878.6	1,257.2	720.0	---	300.0	1,121.9
n	21	7	23	5	0	1	57
Std. Dev.	689.9	2,111.4	1,117.8	576.2	---	---	---
Min	122	450	70	200	0	300	0
Max	3,000	6,000	5,000	1,600	0	300	6,000

What

Table 67. Total Acreage, maximum & minimum values in the sample, mean size and its standard deviation, sample size, and percentile farm size values from 0.1 to 1.0 at 0.1 increments by crop for the mid-South region.

All 4 states							
Crop →	Corn	Cotton	Soybeans	Rice	Peanuts	Grain Sorghum	TOTAL CROPS
Total	161,120	81,339	562,949	207,368	2,595	8,742	1,024,113
Mean	694.5	1,162.0	1,481.4	1,016.5	324.4	397.4	1,118.0
n	232	70	380	204	8	22	916
Std. Dev.	710.5	1,216.8	1,680.2	983.1	290.3	355.0	---
Min	5	45	40	18	15	12	5
Max	4,500	7,000	15,000	6,250	850	1,500	20,050
Percentiles							
P(0.1)	90	300	188	164	40	104	200
P(0.2)	193	396	321	331	62	150	500
P(0.3)	250	500	500	500	92	200	900
P(0.4)	350	515	800	600	176	240	1,200
P(0.5)	450	850	1,000	715	300	300	1,580
P(0.6)	600	1,080	1,300	1,000	420	368	2,000
P(0.7)	800	1,360	1,600	1,200	490	435	2,700
P(0.8)	1,000	1,755	2,189	1,500	500	500	3,400
P(0.9)	1,540	2,104	3,000	2,000	605	800	4,630
P(1.0)	4,500	7,000	15,000	6,250	850	1,500	20,050

13.2 Cover Crops

The survey queried farmers on their use of cover crops; the two posed questions regarding this can be seen in Figure 1. If the answer was positive (i.e.," Yes"), the party then could report the specie of the cover crop(s) and acres planted. The respondent was free to provide additional specie/acreage information as appropriate. While the vast majority of positive replies (77%) reported just a single cover crop, up to four different species/acreages were reported by some farmer respondents. Table 1 shows the results regarding the responses received on cover crops.

Q95

Do you use any cover crops?

- ʘ Yes (1)
- ʘ No (2)
- ʘ Don't Know (3)
- ʘ Prefer not to answer (4)

Q96

What species of cover crops do you use? _________

Please tell me how many acres each crop covers. ______________

Text Box 21. Survey questions series Q95-96 re: Use & type of cover crops

Table 68. Participant responses regarding use of cover crops

Do you use any cover crops?	**Number** of Responses	Number of different species reported on				
		1	2	3	4	Total
(1) Yes	140	140	31	9	3	183
(2) No	325	---	---	---	---	---
(3) Don't Know	1	---	---	---	---	---
(4) Prefer not to answer	0	---	---	---	---	---
Total	466	---	---	---	---	---

In approximately 20% of the cases in which a cover crop was reported, the grower did not supply information regarding the planted acreage. In these instances, the estimated planted acreage in those cases were calculated using a value of 0.50 of the mean of reported acreages for that specie. Also, in the cases where two, three, or four species of cover crop were reported as being grown, but only a single collective acreage amount was provided, then the individual cover crop acreages were prorated equally.

Information regarding irrigators approximately 20% of the cases in which a cover crop was reported, the grower did not supply information regarding the planted acreage. **Figure 48** shows the breakdown on the type of cover crops used on non-rice, irrigated land in the mid-South.

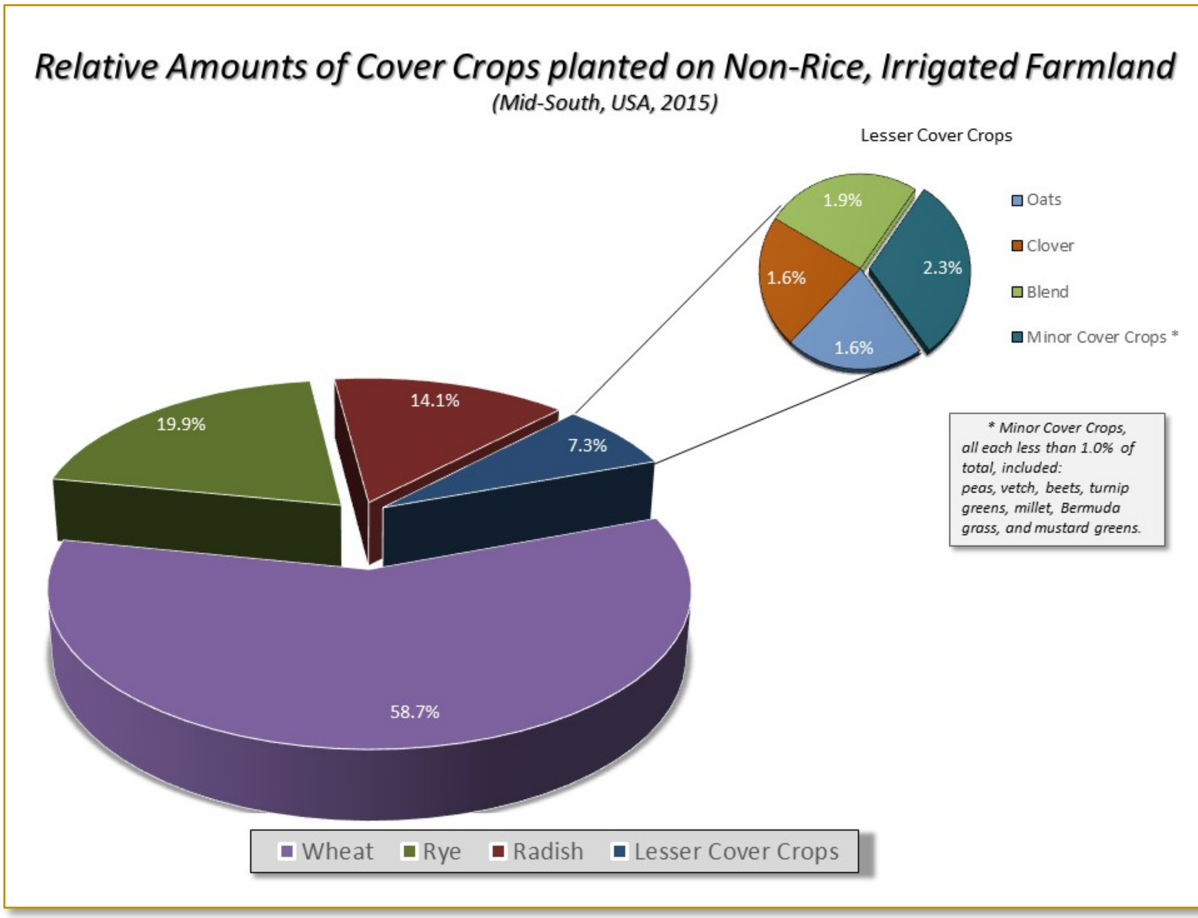


Figure 48. Cover crops grown by mid-South irrigators

13.3 Single Crop Husbandry

Although the funding source for this project came from mid-South soybean farmers, several of the results discovered regarding rice are reported in this paper for several reasons. First, after soybeans, rice was the most widely grown, irrigated crop. Rice growers are highly dependent on soybeans, but the reverse is not necessarily true. However, row-crop farmers in the mid-South owe a large debt of gratitude to rice growers for they were the impetus that introduced laser-controlled land forming to the region. The condition of land surfaces in the mid-South today, is probably twenty years ahead of itself, but for rice being grown locally (plus some dollar a gallon diesel back then). Also, irrigating rice is different enough from irrigating other row crops that some add-on questions were included. Lastly, rice is frequently grown monoculturally; this is the anthesis of soybeans which is nearly always grown in companion with other irrigated crops.

Farm Cropping Patterns. Of the 466 farmers who responded to the survey, 453 provided information regarding their irrigated acreage by crop grown in 2015. Percentage of respondents by state in this regard for AR, LA, MS and MO were 43.7%, 19.4%, 31.6%, and 5.3%, respectively. Almost half (45.0%) of respondents grew some amount of rice. Of the four states, farmers from MS and MO had smaller percentages of irrigation farmers growing rice (19.6 and 20.8%, respectively), while 39.8 of LA and 68.7% of AR irrigated farmers reported that they grew rice in 2015 (**Table 69**).

One distinguishing feature regarding the range of crops irrigators grew on their farm centered around rice. In some states. Two of the five options (row-water and pivot) represented avant-garde irrigation methods for rice.

Table 69. AR, LA, MS, and MO Irrigators from Survey Who Grew Rice in 2015: Sample Size and % of Sample by State, % of Irrigators Who Grew Rice, Average Reported Rice Acreage, and Total Sample Area (Acreage and % of USDA/NASS amounts)

STATE	Sample Size Reporting Some Irrigated Crop (and % total sample) for 2015	% of Respondents Who Grew Rice in 2015	Average Acreage per Rice Grower	Total Acreage from Sample, Growing Rice	Sample Size Relative to USDA/NASS Values [A]
		%	**Acres**	**Acres**	**%**
Arkansas	198 (43.7%)	68.7%	1,072.6	145,873	11.2%
Louisiana	88 (19.4%)	39.8%	916.9	32,090	7.6%
Mississippi	143 (31.6%)	19.6%	921.6	25,805	17.2%
Missouri	24 (5.3%)	20.8%	720.0	3,600	2.0%
All 4 States	453 (100.0%)	45.0%	1,016.5	207,368	10.1%

[A] United States Department of Agriculture / National Agricultural Statistics Service. (2016). Crop Production 2015 Summary. Report: ISSN: 1057-7823. Available at: https://www.usda.gov/nass/PUBS/TODAYRPT/cropan16.pdf.

Unique among the four states, Louisiana rice was very often (74.3%) grown monoculturally. MS and MO had no rice-only farms, while AR had only 2.9% of the farms growing no other crop but rice (**Table 70** and Figure 2).

Table 70. AR, LA, MS, and MO number of irrigators from survey who in 2015 (a) grew no rice, (b) rice along with one or more other crops, (c) monoculturally, and (d) % of monocultural farms.

STATE	Grew No Rice	Grew Rice + Other Crop(s)	Rice Monoculture	Rice Monoculture
				%
Arkansas	62	132	4	2.9%
Louisiana	53	9	26	74.3%
Mississippi	115	28	0	0.0%
Missouri	19	5	0	0.0%
All 4 States	249	174	30	14.7%

Table 71. Number of irrigators in AR, LA, MS, and MO from survey who in 2015 for the crops corn, cotton, soybeans, and rice (a) grew no rice, (b) rice along with one or more other crops, (c) monoculturally, and (d) % of monocultural farms.

Crop	Crop Husbandry Practiced	Location				
		Arkansas	Louisiana	Mississippi	Missouri	All 4 States
	Total Respondents	199	93	148	26	466
Corn	Did NOT grow that crop	42.7%	46.2%	28.4%	7.7%	36.9%
	Monoculture	1.5%	7.5%	5.4%	0.0%	3.9%
	Grew that crop + other crop(s)	55.8%	46.2%	66.2%	92.3%	59.2%
Cotton	Did NOT grow that crop	82.9%	84.9%	66.9%	65.4%	77.3%
	Monoculture	0.5%	1.1%	1.4%	0.0%	0.9%
	Grew that crop + other crop(s)	16.6%	14.0%	31.8%	34.6%	21.9%
Soybeans	Did NOT grow that crop	4.5%	39.8%	11.5%	0.0%	13.5%
	Monoculture	6.0%	10.8%	8.8%	0.0%	7.5%
	Grew that crop + other crop(s)	89.4%	49.5%	79.7%	100.0%	79.0%
Rice	Did NOT grow that crop	29.1%	57.0%	72.3%	73.1%	50.9%
	Monoculture	0.0%	28.0%	0.0%	0.0%	5.6%
	Grew that crop + other crop(s)	70.9%	15.1%	27.7%	26.9%	43.6%

The number of farmers that grew no rice, rice along with one or more other crops, or rice monoculturally by state

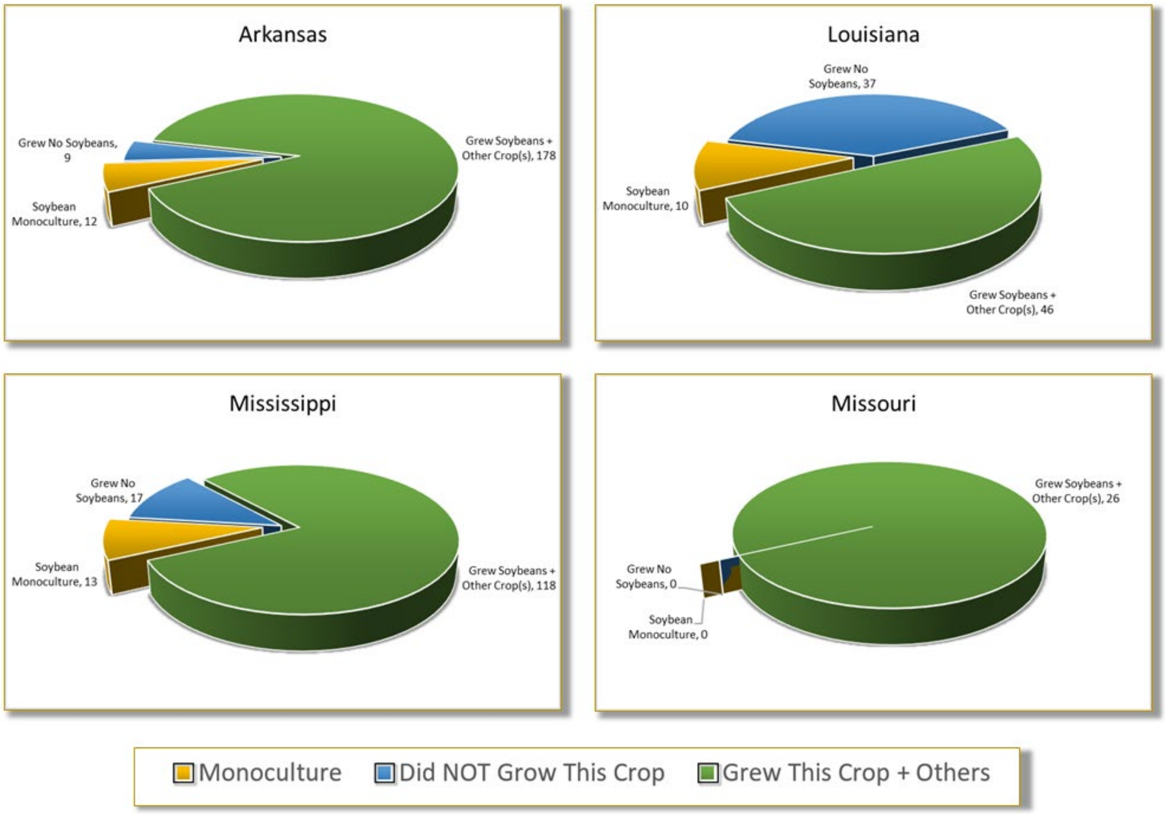


Figure 49. The number of farmers that grew no rice, rice along with one or more other crops, or rice monoculturally by state

13.4 Rice

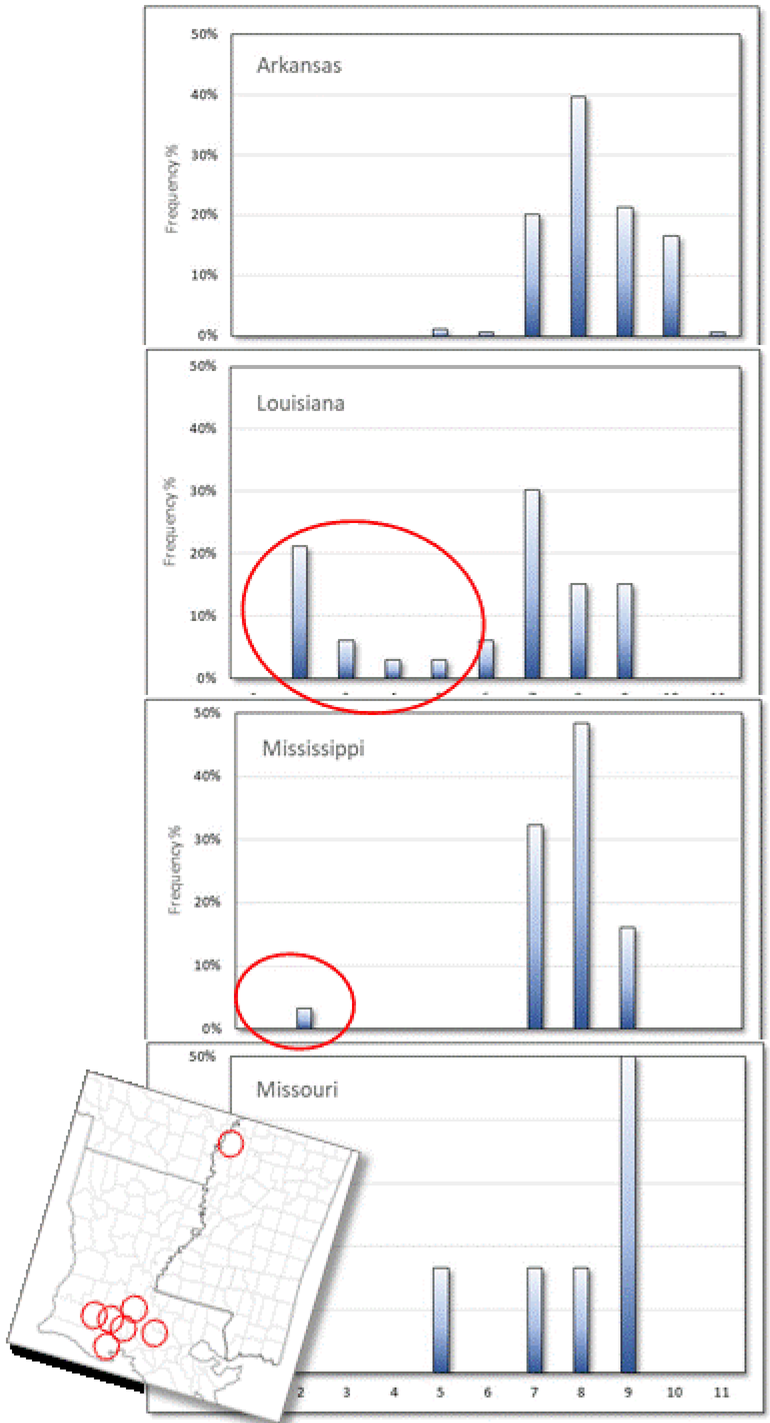
Rice represents a special surveyed crop. It was the second largest cultivated crop. However, more importantly, additional questions were asked about it.

Of the 466 mid-South farmers successfully contacted by phone regarding their crops and irrigation practices, over 400 grew some amount of rice in 2015. Some of the irrigation best management practices (IBMPs) primarily associated with soybean production --and asked about-- included land-forming (zero grade, constant slope, warped slope), irrigation method (flood, furrow, pivot), field alternating (flood/furrow), water capture reservoirs (and source of captured water), field application method, etc.

These additional rice-oriented inquiries can be broadly broken down into:

- The 2015 rice acreage by method of irrigation.

- What % of two of the above (i.e., contour levee & precision grade) used multi-inlet irrigation.
- What percentage of zero grade is continuous rice.
- Regarding PRECISION LEVELING – when, why, why not, funding source.
- Regarding ZERO GRADE – when, funding source.
- Regarding MULTI-INLET – when, why, why not.
- The 2015 rice acreage by <u>method water is run.</u>
- Scheduling methods.



USB Irrigation Project

Figure 50. Histograms of state rice yields showing outliers assumed to be caused by a misunderstanding on units of yield

0 50 100 150 200 250

13.4.1 Special Irrigation Methods used in Rice Cultivation

The ***Q97*** series of questions (shown on the text box below) was meant to establish the percentage of acres used to irrigate rice based on irrigation method. Note that these various methods, though associated with rice cultivation, can also be used with non-rice crops. Two of the five options (row-water and pivot) represented avant-garde irrigation methods for rice.

In 2015, how many acres of rice used each of the following irrigation systems on your farm?

Q97_1 Precision grade ______
- Don't Know (-1)
- Refused (-2)

Q97_2 Contour levee ______
- Don't Know (-1)
- Refused (-2)

Q97_3 Zero grade ______
- Don't Know (-1)
- Refused (-2)

Q97_4 Row-water ______
- Don't Know (-1)
- Refused (-2)

Q97_5 Pivot ______
- Don't Know (-1)
- Refused (-2)

Text Box 13. Survey question series Q97 re: participant's method of irrigating rice

Over all four states, less than half the rice irrigators (46%) used just a single method of irrigation, and 4% actually employed four or five methods of irrigation. **Table 72** shows the percentage of the number of different irrigation methods employed. Mississippi is the state having the most homogenously employment in varieties of rice irrigation methods used where 96% of Mississippi rice growers employed just one or two methods.

Table 73 shows the state by state results. Pivot is the least used method. The other non-typical method (furrow) is actually used on 13% of the rice acres in Arkansas and Missouri. However, the small sample size of the latter state, should be kept in mind. But in Arkansas, where 19 out of the 245 reported irrigation methods used were furrow, more credence is issued there. **Figure 51** graphically presents rice irrigation methods used in the 4-state region collectively, and Figure **52** is a state by state representation of the same.

The use of zero grade in Arkansas, Mississippi, and Missouri only ranged from 1 up to 5%. However, in Louisiana nearly a quarter of the acreage (24.1%) used it, and surprisingly, the amount of zero grade was nearly equal to the amount of contour levee. Again, **Figure 52** graphically exhibits the position of zero grade among other rice irrigation methods, with **Table 73** doing the same in tabular form.

Reported rice yields of the participants is compared to yields published by the USDA/NASS for the years 2013-2015 in **Table 74**.

Table 72. Number of different irrigation methods employed by individual irrigators

Number of Irrigation Methods Used	% of Rice Irrigators
1	46%
2	34%
3	17%
4 or 5	4%

Table 73. Reported acreage of irrigation methods used on rice (and its %) by state

Irrigation Method	Arkansas	Louisiana	Mississippi	Missouri	All 4 States
Precision Grade	95,460 51%	23,242 49%	26,315 87%	3,680 73%	148,697 55%
Contour Levee	54,089 29%	11,610 24%	2,490 8%	600 12%	68,789 25%
Zero grade	9,776 5%	11,566 24%	1,430 5%	60 1%	22,832 8%
Furrow	24,235 13%	1,100 2%	0 0%	670 13%	26,005 10%
Pivot	4,685 2%	400 1%	0 0%	0 0%	5,085 2%

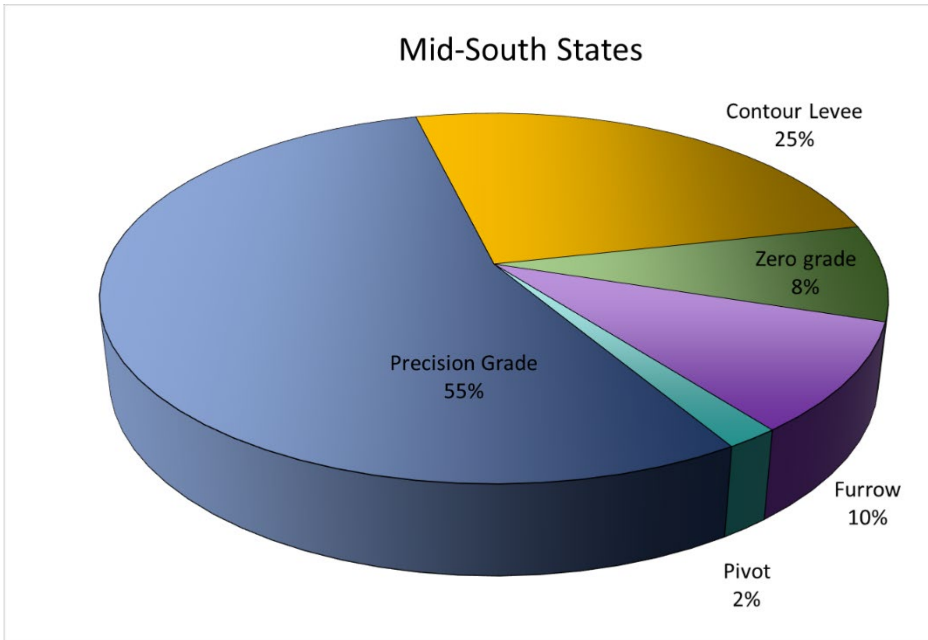


Figure 51. Irrigation methods used to water rice, mid-South

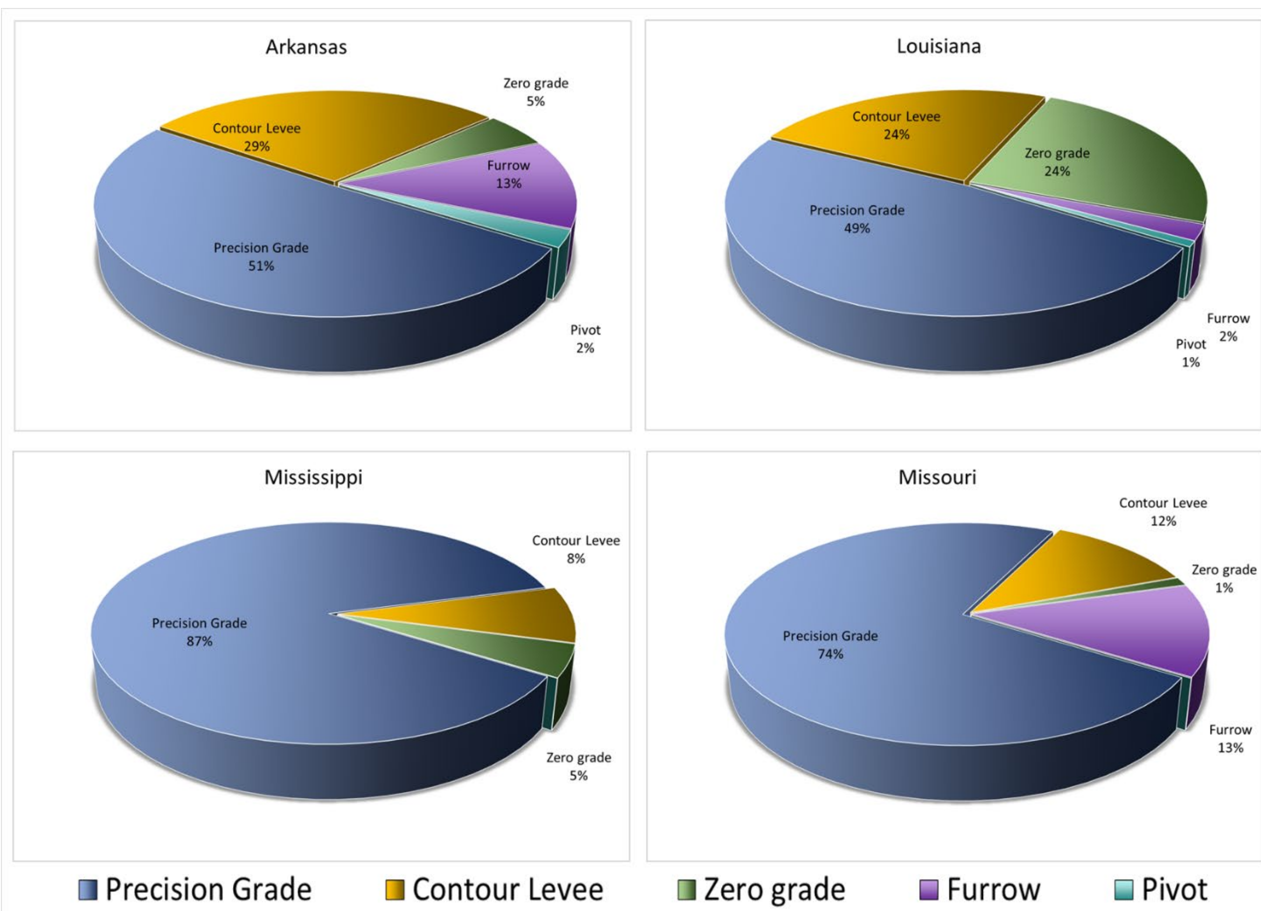


Figure 52. Methods used to irrigate rice, by state

Table 74. Rice yield, standard deviation, sample size and USBIS to NASS yield ration by state

Location	Yield (bu/ac)	St. Dev. (bu/ac)	Ratio of USBIS to USDA/NASS [A] rice yields
Arkansas	176.6 (n = 136)	18.8	1.06
Louisiana	117.7 (n = 37)	60.8	0.74
Mississippi	142.2 (n = 38)	29.2	0.88
Missouri	151.4 (n = 7)	32.0	0.98
All 4 States	159.8 (n = 218)	35.5	0.98

[A] State rice yield average for 2013-2015 (Crop Production 2015 Summary; January 2016. United States Department of Agriculture / National Agricultural Statistics Service. ISSN: 1057-7823)

13.4.2 Applying Rice Water

In 2015, how many rice acres were managed under the following methods?

Q103_1 Continuous Flood ______

Don't Know (-1)

Refused (-2)

Q103_2 Alternate wetting and drying ______

Don't Know (-1)

Refused (-2)

Q103_3 Straight Head Drain ______

Don't Know (-1)

Refused (-2)

Text Box 19. Survey questions series Q103 re: Rice acreage based on water application strategy

13.4.3 Irrigation Scheduling for Rice

Which of the following rice irrigation scheduling tools are utilized on your farm? [Check all that apply]

Q104_1 ☐ Visual Determination

Q104_2 ☐ Calendar Event

Q104_3 ☐ Float Indication

Q104_4 ☐ Electronic Sensor

Q104_5 ☐ Other

Q104_5_other (Please specify) ____________________

Text Box 20. Survey questions series Q104 re: Rice irrigation scheduling methods

13.4.4 Rice Acreage

Rice was unique among the four major examined crops because the participant's acreage of it could be calculated from a planted crop- and irrigation method-basis, as were all the other major crops, but then again from two other methods involving rice water methods and land forming practices. These acre-counting methodologies were:

- 2015 planted rice acreage (Q137_4)
- Rice watering methods (Σ Q103_1 … Q103_3)
- Rice irrigation management practices (Σ Q97_1 … Q97_5)
- Land forming ([Q137_4] / [Σ Q137_1 … Q137_7])

Table 75 lists these four methods and the average, total and number of acres for each method, as well as the associates survey question numbers.

Table 75. The four methods that rice acreage could be determined

Location	Statistic	Your 2015 Rice Acreage?	Sum of Rice Watering Methods	Sum of Rice Acres by Irrigation Method	Total Land Leveled - Zeroes Removed
		Q137_4	Σ Q103_1 … Q103_3	Σ Q97_1 … Q97_5	(Q137_4) / (Σ Q137_1 … Q137_7)
Arkansas	Sum	145,873	148,578	188,245	340,354
	(n)	(136)	(128)	(130)	(176)
	Average	1072.6	1160.8	1448.0	1933.8
Louisiana	Sum	32,090	28,572	47,918	117,605
	(n)	(35)	(31)	(34)	(79)
	Average	916.9	921.7	1409.4	1488.7
Mississippi	Sum	25,805	25,450	30,235	243,157
	(n)	(28)	(28)	(28)	(124)
	Average	921.6	908.9	1079.8	1960.9
Missouri	Sum	3,600	3,840	5,010	52,820
	(n)	(5)	(6)	(6)	(21)
	Average	720.0	640.0	835.0	2515.2
All 4 States	Sum	207,368	206,440	271,408	753,936
	(n)	(204)	(193)	(198)	(400)
	Average	1016.5	1069.6	1370.7	1884.8

In contrasting the results derived from the reported 2015 planted rice acreage (***Q137_4***) method to those arrived at using the sum of the rice watering methods (***Σ Q103_1 … Q103_3***), it is seen that in 68% of the cases the two pairs of acreage amounts are equal. However, when contrasting results derived from ***Q137_4*** to those derived the rice irrigation method query (***Σ Q97_1 … Q97_5***) only 42% of the acreage amount values match one another.

Figure 53 shows state by state comparisons of individuals' reported irrigated acreage based on their 2015 reported planting amounts to that of the sum acres using different rice watering management strategies.

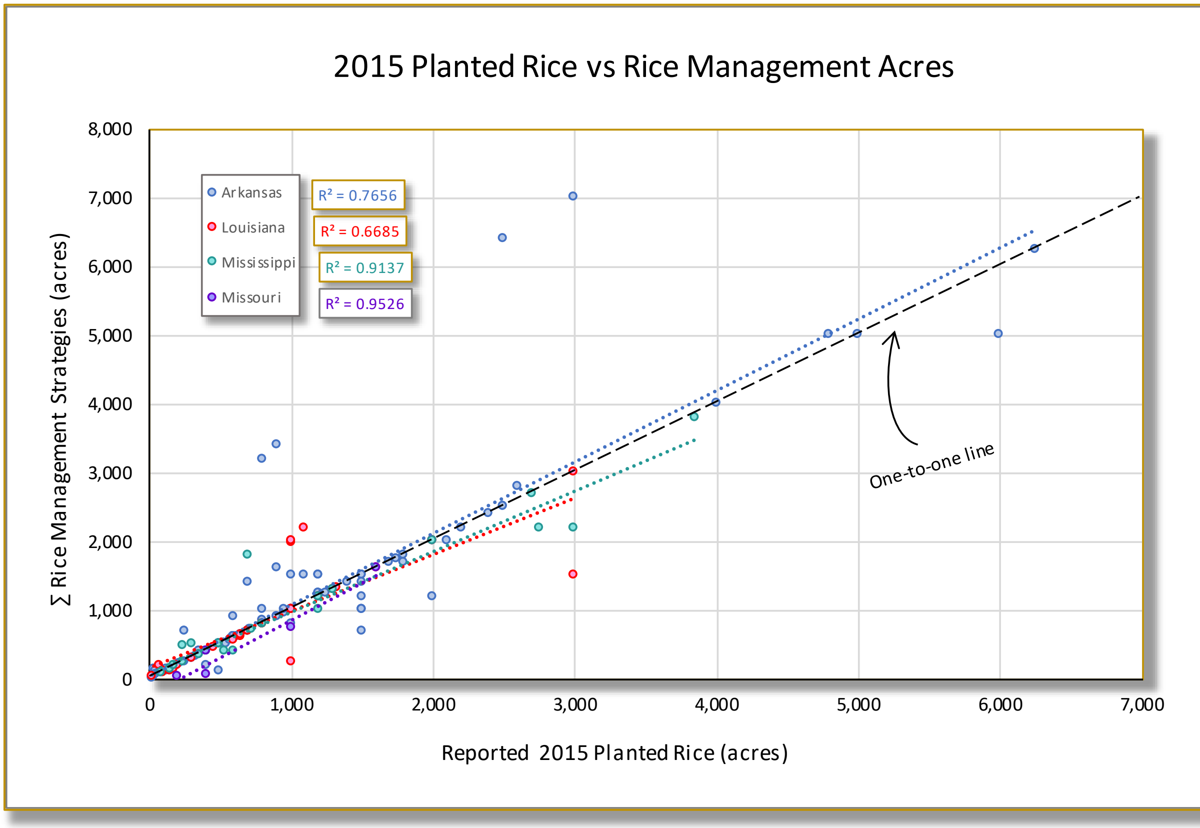


Figure 53. Individuals' reported irrigated acreage based on 2015 planting values to sum of rice watering management strategies.

Text Box 4. Survey question series Q47; a secondary means to estimate irrigation acreage

In 2015, how many rice acres were managed under the following methods?

Q103_1 Continuous Flood ______
Don't Know (-1)
Refused (-2)
Q103_2 Alternate wetting and drying ______
Don't Know (-1)
Refused (-2)
Q103_3 Straight Head Drain ______
Don't Know (-1)
Refused (-2)

Text Box 5. Survey question series Q103: a means to compare estimated irrigated acreage

In 2015, how many acres of rice used each of the following irrigation systems on your farm?

Q97_1 Precision grade
Don't Know (-1)
Refused (-2)
______ *acres*
Q97_2 Contour levee
Don't Know (-1)
Refused (-2)
______ *acres*
Q97_3 Zero grade
Don't Know (-1)
Refused (-2)
______ *acres*
Q97_4 Row-water
Don't Know (-1)
Refused (-2)
______ *acres*
Q97_5 Pivot
Don't Know (-1)
Refused (-2)
______ *acres*

Text Box 6. Survey question series Q97: a means to compare estimated irrigated acreage

Table 76. 2015 planted acreage of all crops and for rice and their ratio

Location	2015 Planted Acres, All Crops	2015 Planted Acres, Rice	Rice / All Crops
	Σ (Q137_1 … Q137_6)	Q137_4	(%)
Arkansas	493,332 (198)	145,873 (142)	29.6%
Louisiana	139,216 (88)	32,090 (39)	23.1%
Mississippi	327,618 (143)	25,805 (41)	7.9%
Missouri	63,947 (24)	3,600 (6)	5.6%
All 4 States	1,024,113 (453)	207,368 (228)	20.2%

As mentioned, rice had the advantage of having additional methods for deriving (and double-checking) participants' rice acreage other than just the straight-forward 2015 planted rice acreage value provided in ***Q137***. shows how closely these summation methods reflect one another by exhibiting the ratio of the reported 2015 rice acres relative to that calculated by these three other indices: Rice Management Practices (***Q103***), employed Irrigation Methods (***Q97***), and improved Land Forming (***Q47***). The employed Irrigation Methods (***Q97***), earlier referred to as ***RI***, is one of the three units (the other two being ***GI*** and ***PS***), used in calculating ***Acres$_{IM}$***. Ratios relative to ***Q103*** and ***Q97***, are very good, 0.996 and 1.309, respectively, especially since using total crops of all 466 respondents the ratio was about 1.70.

The down side of this is that only 26 of all respondents –all in Louisiana—solely grew rice. However, being cognizant of the apparent rice-related accuracy in the study, filters into other considerations and discussions since rice, second only to soybeans, made up a relatively large portion (20%) of all respondent acreage.

Table 77. Ratio of reported 2015 acres to that of management practices, irrigation methods and land leveling; sample size: (n)

Location	2015 Rice Acreage	Rice Acres by Rice Management Practices	Rice Acres by Rice Irrigation Method	Rice Acres by Improved Land Forming
	Q137_4	Σ Q103_1 … Q103_3	Σ Q97_1 … Q97_5	Σ Q47_1 … Q47_3
Arkansas	1.000 (136)	1.019 (128)	1.290 (130)	0.971 (176)
Louisiana	1.000 (35)	0.890 (31)	1.493 (34)	0.966 (79)
Mississippi	1.000 (28)	0.986 (28)	1.172 (28)	0.858 (124)
Missouri	1.000 (5)	1.067 (6)	1.392 (6)	1.077 (21)
All 4 States	1.000 (204)	0.996 (193)	1.309 (198)	0.941 (400)

As discussed, crop acreage derived from the ***Q147*** series of questions on the six crops only had partial correspondence to sums derived from irrigation method summation. However, when rice is viewed separately as shown above, there was much better agreement. Additionally, the *USBIS* and the 2013 USDA/NASS are very similar, as seen in **Figure 54**.

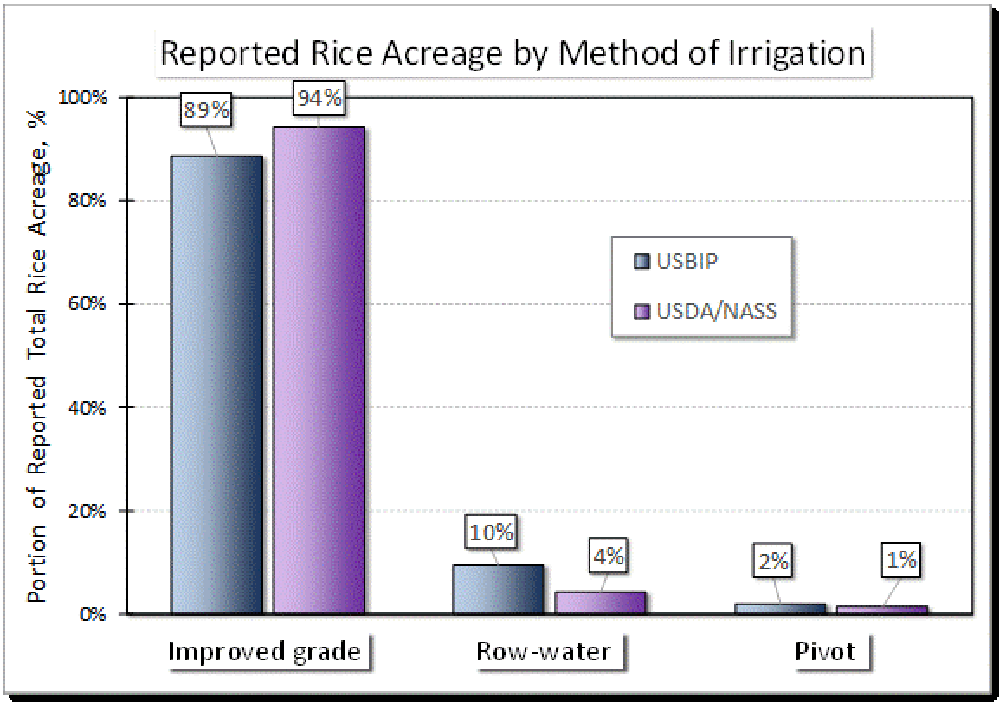


Figure 54. Comparing rice irrigation methods from *USBIP* and USDA/NASS

13.4.1 Irrigated Row Crop / Rice Acreage

13.5 Soybean

As mentioned previously, soybeans were grown more than any other crop. This can be explained for assorted reasons: it is a good rotational crop (it is one of only a few rotational crops for rice), cultivation costs are relatively low, N-application for a subsequent corn crop can be reduced, its window for planting is relatively large, etc. Additionally, it is possible that some of the non-growers of irrigated soybeans may have had acreages of dryland soybeans.

Soybeans in this region are generally watered using surface irrigation, especially in the three southern-most states.

13.5.1 Non-soybean Growers.

There were no Missouri respondents not growing soybeans. The 15% of participants in the survey that did not grow soybeans then came from the three other states in the survey. Some of the particulars between the two groups follow.

The average number of years of irrigation experience for both groups was a little over 30 years, with non-growers having slightly more (table 19).

Table 78. The years of irrigation experience (and s.d.) for those who did/didn't grow soybeans

Location	Had irrigated soybeans	Did NOT have irrigated soybeans
Arkansas	32.8 (15.33)	32.4 (16.76)
Louisiana	30.9 (13.79)	34.6 (14.77)
Mississippi	28.1 (13.86)	29.4 (19.85)
Missouri	35.6 (13.83)	--- ---
All 4 States	31.2 (14.71)	32.9 (16.42)

14 Methods of Irrigation

Acreage Amounts as Collected. In the survey interview process, the categories of irrigation methods were broadly grouped into three discernible types. 1) Rice (this particular crop, since it has its own sub-groups of irrigation methods not relative to other row crops [e.g., contour levee and zero-grade]) became a main category in and of itself. 2) Pressurized on non-rice crops includes both fixed and towable pivots; also tacked on to this category are the few acres of drip irrigation found in the survey; side-roll irrigation was not asked about in the study. 3) Gravity on non-rice crops is a generic term for all gravity methods (e.g., furrow, border, basin, etc.) on row crops.

Acreage Amounts as Analyzed. It was desired that the data collected using the survey's three subgroups above also be presented within traditional irrigation categories so as to comport with professional approaches. For example, the 5,008 acres of rice seen in the survey that were irrigated with pivots would be totalized up under pressurized/pivot. In this regard then there would be two main groupings: 1) Gravity Irrigation and 2) Pressurized Irrigation. **Table 79** shows how irrigated acreage data was collected and then appropriately categorized for analysis plus the various survey questions used.

Table 79. How acreage data was collected and analyzed

As Collected in Survey	
Category	Survey Questions
Rice Irrigation	Q97_1, Q97_2, Q97_3, Q97_4, & Q97_5
Pressurized (row crop)	Q32, Q62 & Q63
Gravity (row crop)	Q28b, Q28c, & Q30
As Finally Analyzed	
Category	Survey Questions
Gravity (all crops)	
Furrow (all crops)	Q28b, Q28c, & Q97_4
Flood/Border (all crops)	Q30, Q97_1, Q97_2, & Q97_3
Pressurized (all crops)	Q32, Q62, Q63, & Q97_5

Table 80 and **Table 81** provide sample size, sum, and mean by state for the various irrigation methods. The former table reflects how the data was gathered in the survey instrument, while the later table presents the information on irrigation methods in a more traditional form.

The first paper published using these survey results (Northern Economics, Inc. [2017]), had separated the various irrigation methods differently from shown in **Table 79**. They included an additional column of data containing acre values (***Q28a***) that should not have been used in summing acreage. This led to the conclusion that acres by irrigation method significantly exceeded acres by 2015 crop planted acreage. This will be explained more in 14.1.2 Gravity Irrigation Systems.

Table 80. Acreage Data (number, sum and mean) by state as collected in the survey

Acreage Data as Collected in the Survey																	
Locale	Stat Used	Rice Irrigation						Pressurized (row crop)				Gravity (row crop)				All Methods
		$G_{B/F}$	$G_{B/F}$	$G_{B/F}$	G_R	P		P	P	P		$G_{B/F}$	G_R	$G_{B/F}$		
		Precision grade (Q97_1)	Contour levee (Q97_2)	Zero grade (Q97_3)	Row-water (Q97_4)	Pivot (Q97_5)	Rice Methods	Drip (Q32)	Regular pivot (Q62)	Towable pivot (Q63)	Pressurized Methods	Exclusively flood (Q28_b)	Continuously furrow (Q28_c)	Border (Q30)	Gravity Methods	
AR	N	107	80	35	19	4	245	2	59	10	71	134	158	21	313	629
LA	N	25	18	17	1	1	62	2	22	0	24	15	56	6	77	163
MS	N	25	7	5	0	0	37	4	80	8	92	38	116	7	161	290
MO	N	6	1	1	2	0	10	1	16	3	20	7	16	2	25	55
All 4 States	N	163	106	58	22	5	354	9	177	21	207	194	346	36	576	1,137
AR	$\sum$	95,460	54,089	9,776	24,235	4,685	188,245	260	53,320	2,327	55,907	142,482	236,859	13,205	392,546	636,698
LA	$\sum$	23,242	11,610	11,566	1,100	400	47,918	240	19,110	0	19,350	11,554	85,961	2,287	99,802	167,070
MS	$\sum$	26,315	2,490	1,430	0	0	30,235	643	72,318	1,770	74,731	32,995	183,637	2,735	219,367	324,333
MO	$\sum$	3,680	600	60	670	0	5,010	400	19,813	880	21,093	3,610	42,192	6,400	52,202	78,305
All 4 States	$\sum$	148,697	68,789	22,832	26,005	5,085	271,408	1,543	164,561	4,977	171,081	190,641	548,649	24,627	763,917	1,206,406
AR	$\bar{x}$	892	676	279	1,276	1,171	768	130	904	233	787	1,063	1,499	629	1,254	1,012
LA	$\bar{x}$	930	645	680	1,100	400	773	120	869	---	806	770	1,535	381	1,296	1,025
MS	$\bar{x}$	1,053	356	286	---	---	817	161	904	221	812	868	1,583	391	1,363	1,118
MO	$\bar{x}$	613	600	60	335	---	501	400	1,238	293	1,055	516	2,637	3,200	2,088	1,424
All 4 States	$\bar{x}$	912	649	394	1,182	1,017	767	171	930	237	826	983	1,586	684	1,326	1,061

Table 81. Acreage Data (number, sum and mean) by state arranged by traditional method groups

Acreage Data as Analyzed																	
Locale	Stat Used	Gravity Irrigation										Pressurized Irrigations					All Methods
		Furrow			Border / Flood						All Gravity Irrigation						
		G_R	G_R	Furrow Method	$G_{B/F}$	$G_{B/F}$	$G_{B/F}$	$G_{B/F}$	$G_{B/F}$	Border / Flood Methods		P	P	P	P	Pressurized Methods	
		Continuously furrow	Row-water		Exclusively flood	Border	Precision grade	Contour levee	Zero grade			Drip	Regular pivot	Towable pivot	Pivot		
AR	N	158	19	177	134	21	107	80	35	377	554	2	59	10	4	75	629
LA	N	56	1	57	15	6	25	18	17	81	138	2	22	0	1	25	163
MS	N	116	0	116	38	7	25	7	5	82	198	4	80	8	0	92	290
MO	N	16	2	18	7	2	6	1	1	17	35	1	16	3	0	20	55
All 4 States	N	346	22	368	194	36	163	106	58	557	925	9	177	21	5	212	1,137
AR	$\sum$	236,859	24,235	261,094	142,482	13,205	95,460	54,089	9,776	315,012	576,106	260	53,320	2,327	4,685	60,592	636,698
LA	$\sum$	85,961	1,100	87,061	11,554	2,287	23,242	11,610	11,566	60,259	147,320	240	19,110	0	400	19,750	167,070
MS	$\sum$	183,637	0	183,637	32,995	2,735	26,315	2,490	1,430	65,965	249,602	643	72,318	1,770	0	74,731	324,333
MO	$\sum$	42,192	670	42,862	3,610	6,400	3,680	600	60	14,350	57,212	400	19,813	880	0	21,093	78,305
All 4 States	$\sum$	548,649	26,005	574,654	190,641	24,627	148,697	68,789	22,832	455,586	1,030,240	1,543	164,561	4,977	5,085	176,166	1,206,406
AR	$\bar{x}$	1,499	1,276	1,475	1,063	629	892	676	279	836	1,040	130	904	233	1,171	808	1,012
LA	$\bar{x}$	1,535	1,100	1,527	770	381	930	645	680	744	1,068	120	869	---	400	790	1,025
MS	$\bar{x}$	1,583	---	1,583	868	391	1,053	356	286	804	1,261	161	904	221	---	812	1,118
MO	$\bar{x}$	2,637	335	2,381	516	3,200	613	600	60	844	1,635	400	1,238	293	---	1,055	1,424
All 4 States	$\bar{x}$	912	1,182	1,562	983	684	912	649	394	818	1,114	171	930	237	1,017	831	1,061

Broadly speaking, irrigation can be divided into two main categories defined from the method of energy used transferring the irrigation water throughout the field. Gravity irrigation involves differences in water surface height to advance water in the direction of the gradient ("water flows downward"). Examples from the survey include furrow and border irrigation. Within the survey, the latter method, border, was broken down into 0-grade, precision grade, and contour levee. In some instances, fields that may have at times been furrow irrigated by water advancing down the furrow stream which lays between the shoulders of two beds, can at other times --by knocking the beds lower or by increasing flow onto the field-- have the field become inundated as water advances downstream. The former case is an example of furrow, while the latter is an example of border.

Even though a pump may have been used to lift and deliver water in a pressurized conveyance system to the edge of the field, it is still gravity that moves it within a field. The other main irrigation method in the survey is pressurized irrigation, and in the survey included center pivots (fixed and towable types) and micro-irrigation (a.k.a., drip irrigation), although there are several other forms of pressurized irrigation.

The majority of irrigation used in the mid-South involves gravity irrigation. In terms of area involved it is 86%, and in terms of users it is 94%. **Table 82** shows involved acres and number of users of for gravity and pressurized irrigation. Since many farmers employ both methods of irrigation, combining percent of the ***users*** of gravity method and the pressurized method > 100% (e.g., for all four states these two values are 93.4% and 42.4%, which is 135.8%). However, performing the computation on the ***acres*** involved yields 100%.

Table 82. Differences by state in gravity and pressurized irrigation: number of users and area.

Users					
	All Methods	Gravity Irrigation Methods		Pressurized Irrigation Methods	
	# of Users	# of Users	% of Users	# of Users	% of Users
AR	190	186	97.9%	62	32.6%
LA	90	84	93.3%	24	26.7%
MS	137	124	90.5%	84	61.3%
MO	24	18	75.0%	17	70.8%
All 4 States	441	412	93.4%	187	42.4%
Acres					
	All Methods	Gravity Irrigation Methods		Pressurized Irrigation Methods	
	# of Acres	# of Acres	% of Acres	# of Acres	% of Acres
AR	636,698	580,791	91.2%	55,907	8.8%
LA	167,070	147,720	88.4%	19,350	11.6%
MS	324,333	249,602	77.0%	74,731	23.0%
MO	78,305	57,212	73.1%	21,093	26.9%
All 4 States	1,206,406	1,035,325	85.8%	171,081	14.2%

Approximately 58% of respondents used only gravity irrigation, 36% employed both gravity and pressurized irrigation, and 7% only used pivot.

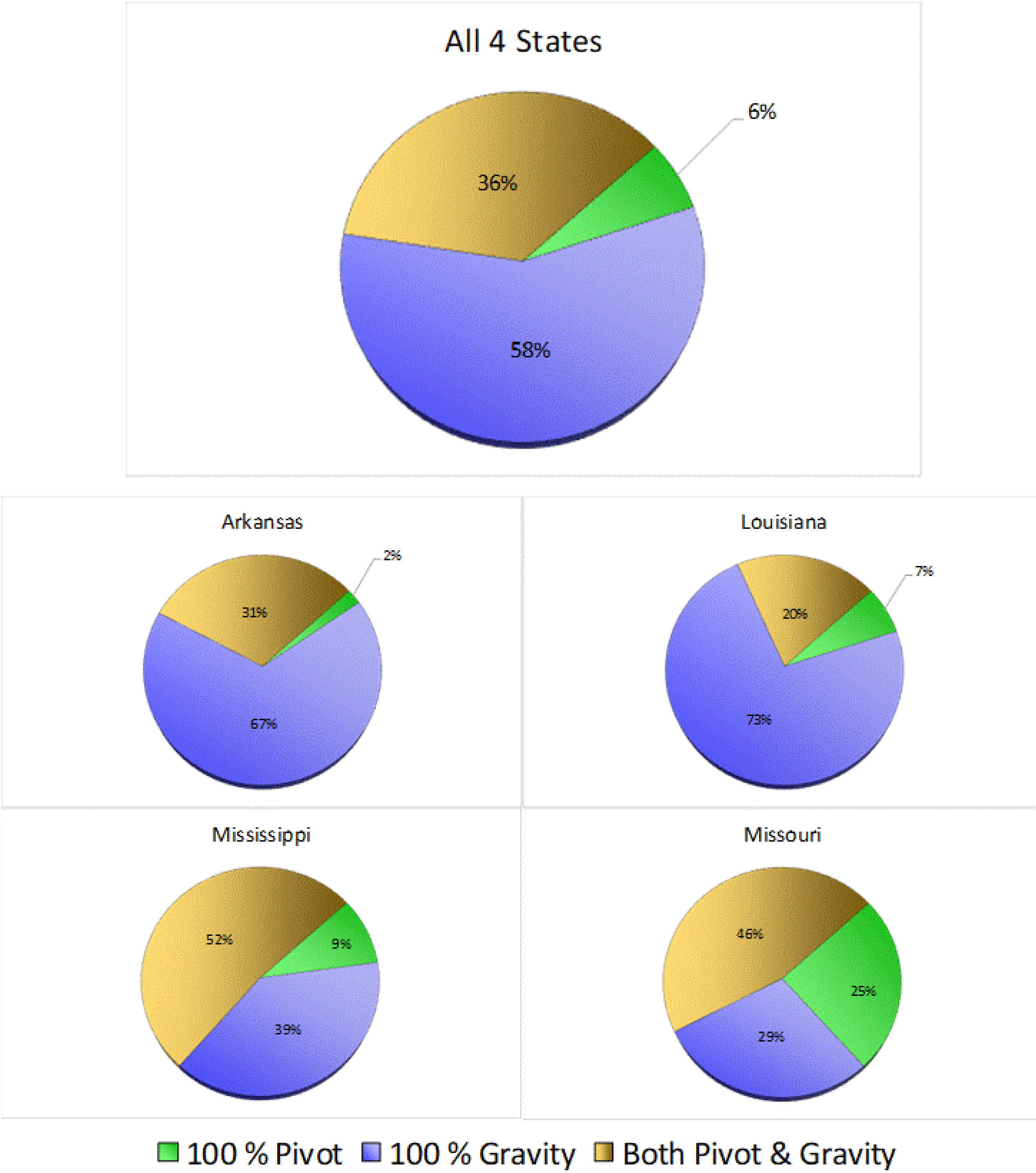


Figure 55. Portions of users who have all pivot, all gravity, or a combination of pivot and gravity.

Figure 56 shows these demarcation categories for the 1½ million identified acres of irrigation found in the study for the entire 4-state region. Rice, generically composed of its several sub-categories, involved 18% of the acreage. Surprisingly, pivot (representing all identified pressurized irrigation systems) was only at 11%, substantially smaller than the amount of irrigated rice. Flood irrigation on non-rice crops at 71% represented almost three fourths of the irrigation methods found in the mid-South.

Figure 57 graphically shows these same data broken down by state. The data for Missouri, comprised of just a sample size of 26 irrigators, may represent an anomaly, with the amount of pivot irrigation under reported.

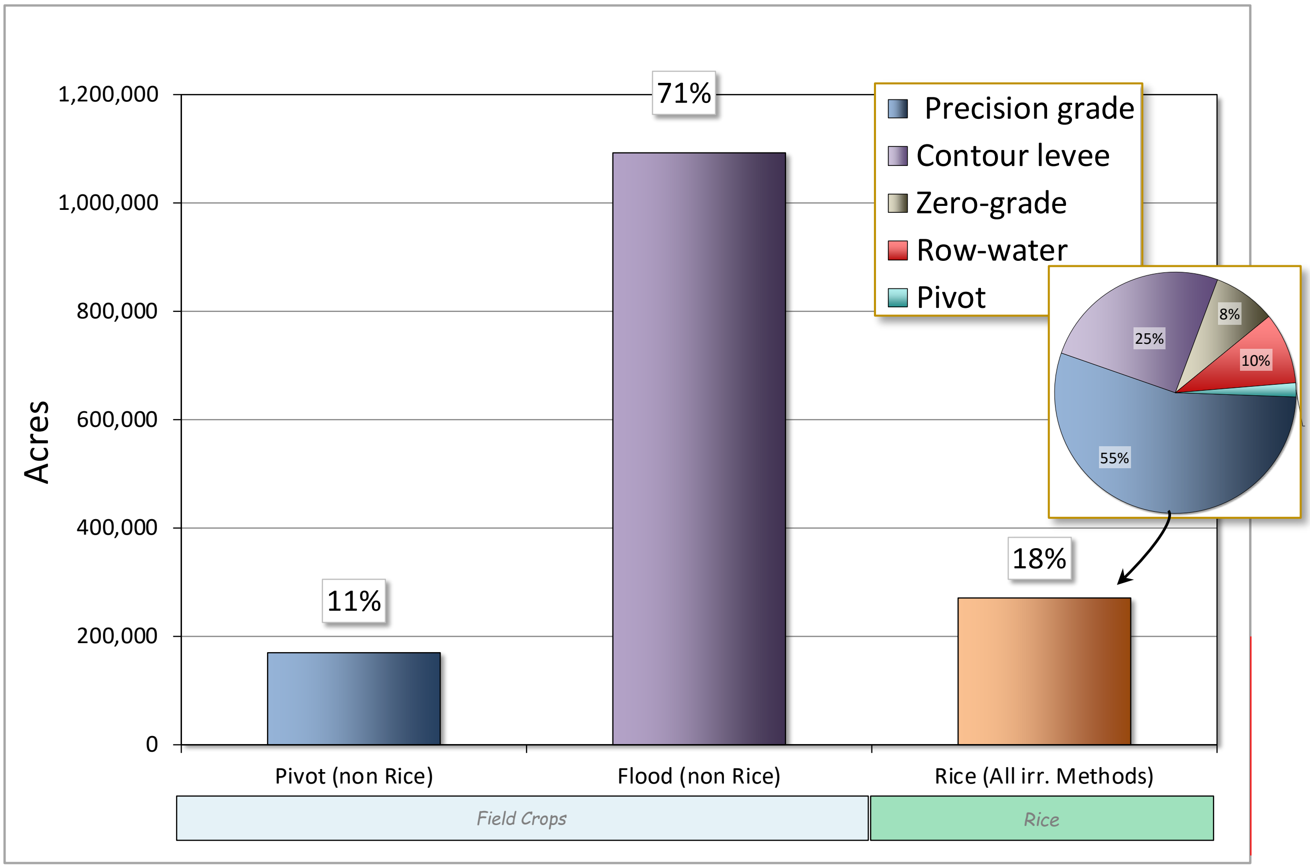


Figure 56. Main broad grouping of irrigation methods (pivot & flood [i.e., all gravity methods) and all forms on rice). Rice methods broken down in pie chart – all 4 states

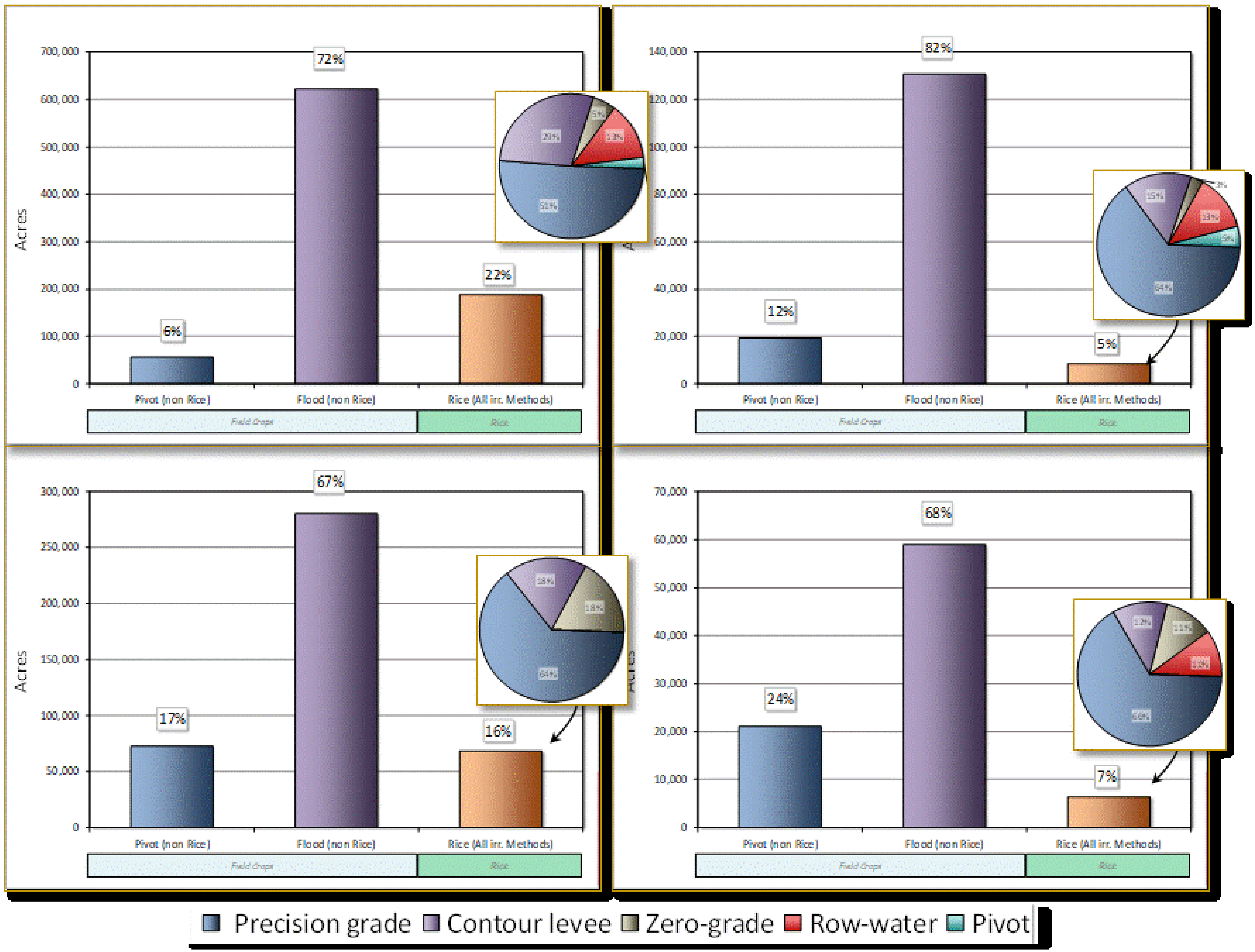


Figure 57. Main broad grouping of irrigation methods (pivot & flood) and all forms on rice). Rice methods broken down in pie chart – by state (clockwise, starting at Top Left: AR, LA, MO, and MS

14.1 Types of Irrigation Systems

14.1.1 Pressurized Systems (e.g., center pivots)

Drip Irrigation. Pressurized irrigation methods included center pivots (both permanent and towable) and drip irrigation. There were only 1,543 acres of drip, making it slightly less than 1% of all pressurized acres. The average total acre size for farms (there was just 9 of them) that had drip was only 649 acres. In two instances the drip acreage represented the totality of the farmer's irrigated acres.

Center Pivot. Only 17.4 % of mid-South irrigated acres are watered with center pivots. Missouri is the state with the largest percent of acreage (41%) with 7 out of every 10 of its irrigators employing some amount of pivot irrigation. On average, the pivot owner will have nearly three times as many acres using gravity methods of irrigation as he does his pivot-irrigated acres (**Table 83**).

Table 83. Center pivot acreage, number and % (by area and user) and information about pivot owners' gravity irrigated acreage

Locale	All Pivots	N	% Pivots Represent		If a pivot is owned		
			In acres	In users	His pivot acreage	His gravity acreage	Gravity to pivot ratio
	(Acres)		(%)	(%)	(Acres)	(Acres)	
Arkansas	55,647	61	9.8%	32.1%	912	3,640	4.0
Louisiana	19,110	22	10.9%	24.4%	869	2,544	2.9
Mississippi	74,088	81	28.2%	58.7%	915	1,981	2.2
Missouri	20,693	17	40.5%	70.8%	1,217	2,966	2.4
All 4 States	169,538	181	17.4%	41.0%	937	2,728	2.9

The preponderance of pivot-irrigated acreage is done using fixed pivots (97.1%) as seen in **Table 84**. For the entire mid-South region towable pivots irrigated only about 5,000 acres.

Table 84. Ratio of fixed pivots to towable pivots

Locale	Fixed Pivots		Towable Pivots		% Fixed pivot to all pivots	
	(acres)	(N)	(acres)	(N)	By acreage	By users
Arkansas	53,320	59	2,327	10	95.8%	85.5%
Louisiana	19,110	22	0	0	100.0%	100.0%
Mississippi	72,318	80	1,770	8	97.6%	90.9%
Missouri	19,813	16	880	3	95.7%	84.2%
All 4 States	164,561	177	4,977	21	97.1%	89.4%

Interestingly, the towable pivot appears to be a gateway to fixable pivot use. In Questions ***Q60*** and ***Q61*** a key phrase was "(h)ave you ever used", implying that the concept of "formerly used" was in play. The follow up questions of ***Q62*** and ***Q63*** queried for the 2015 acreage for each of these systems. Only about 14% of the people who had previously responded YES to using fixed pivots, went on to report no 2015 acreage of fixed pivots. On the other hand, in the case of towables this figure was 67% (**Table 85** and **Figure 58**). Apparently, many people who had formerly used towables, were no longer using them in 2015. Additionally, 74% of all respondents who had answered YES regarding if they had ever used towable pivots, were in 2015 using fixed center pivots (**Table 86**). Irrigation dealers have commented in the past that they didn't mind losing a current pivot sale to a farmer who was trying to irrigate two or more fields with a single towable, as farmers, they said, generally came around to purchase another one freeing them from the task of towing.

Figure 58 Illustrates the continuity of use for six irrigation methods in the mid-South by showing the percentage of respondents who indicated that they "ha(d) ever used" the practice but then recorded no 2015 acreage. Towable pivots and field crop border irrigation were the two irrigation methods with the largest amounts of system disuse.[21]

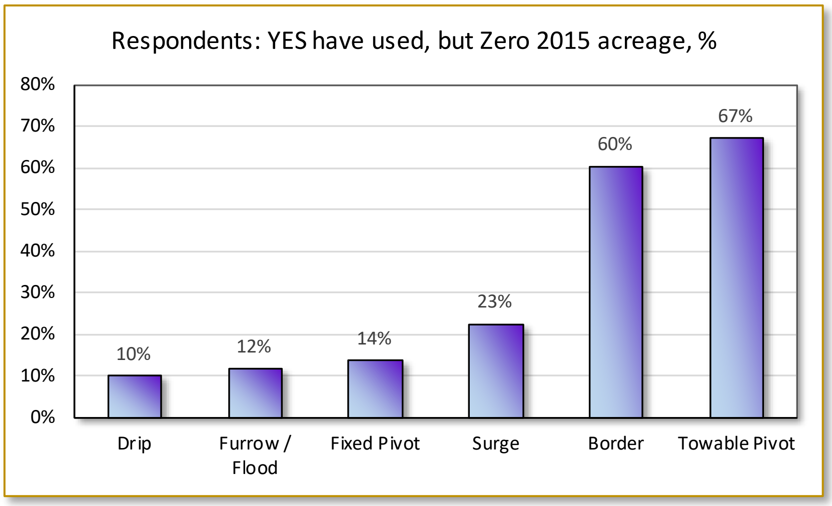


Figure 58. % of respondents who indicated YES but listed no 2015 acres for 6 irrigation methods.

Table 85. Proportion of farmers indicating having used fixed and towable pivots and exhibiting 2015 acreage in the same

Locale	Fixed Pivot				Towable Pivot			
	YES & some 2015 Acres	YES & **NO** 2015 Acres	Total YESs	% NO Acres	YES & some 2015 Acres	YES & **NO** 2015 Acres	Total YESs	% NO Acres
	(N)	(N)	(N)	(%)	(N)	(N)	(N)	(%)
Arkansas	59	13	72	18.1%	10	21	31	67.7%
Louisiana	22	6	28	21.4%	0	5	5	100.0%
Mississippi	80	6	86	7.0%	8	16	24	66.7%
Missouri	16	3	19	15.8%	3	1	4	25.0%
All 4 States	177	28	205	13.7%	21	43	64	67.2%

[21] N.B.: The actual rates of disuse is most likely lower than indicated as the few responses of "Refused", "Don't Know", or no answer given were taken to assume NO acreage.

Table 86. Percentage of sample who had indicated YES regarding towable pivots & had 2015 fixed pivot acreage

Locale	Indicated HAD USED towable pivot			% having 2015 FIXED pivot acreage
	Had some amount of 2015 FIXED Pivot acreage?		TOTAL	
	YES	NO		
Arkansas	22	10	32	68.8%
Louisiana	3	2	5	60.0%
Mississippi	20	4	24	83.3%
Missouri	3	1	4	75.0%
All 4 States	48	17	65	73.8%

Additionally, respondents were asked about the following practices related to improving center pivot irrigation.

Q66_1 Drop nozzles Q66_2 End guns Q66_3 Rotators Q66_4 Variable rate irrigation Q66_5 Corner Unit

14.1.2 Gravity Irrigation Systems

The Correct Components for Summing Gravity System Acreage. For field crops, the final tally of acreage for gravity irrigation methods should be comprised of the responses from the three questions: "Exclusively flood" (***Q28b***), "Continuously furrow" (***Q28c***), and Border (***Q30***). However, one other one (***Q28a***), had immediately preceded these three question; it read "*Of your total irrigated acres, how many acres alternate between flood and furrow irrigation? Such as levee rice and row watered soybeans."* This question appeared to have infused an element of confusion, not only to some of the participants, but also to the experts involved with the data analysis early on.

Northern Economics, Inc. (2017), dealing just with the Arkansas data, stated that: "*Total irrigated acres by irrigation method is different from total irrigated acres by crop"*; they showed 1,022,056 irrigation system acres[22], while tallying only 600,747 crop acres, a ratio of 1.70 $\boldsymbol{Acres_{IM}}$ to 1.00 $\boldsymbol{Acres_{CG}}$. Reviewing the questions and responses used in deriving their totalized value of $\boldsymbol{Acres_{IM}}$, it appears that ***Q28a*** was one part of the dataset that was employed. However, ***Q28a*** is not an "all-inclusive question," (as described earlier [c.f.,**3.5 All-inclusive Question Series**]), and as such, should not to be used for tabulation. The fact that the phrase "irrigated in 2015" is not included within the text of this particular question supports this conclusion.

That question sought to determine if farmers might have fields set up to be furrow irrigated one year and perhaps then in a following year be irrigated using flood, or vices versa, and if so, how many of his acres were involved in rotating irrigation methods. The number of acres involved in rotation (***Q28a***) cannot be greater than the combined totals of the "exclusively flood" (***Q28b***) and "continuously furrow" (***Q28c***); but this occurred 15.7% of the time. Additionally, if all of one's furrow- and flood-irrigated fields are part of the rotation than Q28a = (Q28a + Q28a), and this occurred with 16.4% of the respondents. This last quantity would be synonymous to 1 out of every 6 irrigators providing values such that the sum of his furrow and flood acres was the acreage amount held in rotation. Other than respondent actually understanding that ***Q28a*** did represent the sum of ***Q28b*** and ***Q38c***, the occurrence of this (i.e., Q28a = [Q28a + Q28a]) happening seems unlikely if

[22] Their calculations as seen in Table 5 was 716,470 acres (giving a ratio of 1.19). My calculation was derived from the pertinent columns from Tables 7 and 8 being added to the Table 5 data.

each of the three inputs were felt to be separate irrigation methods. This is especially so in light of the randomness of some of the trio of values (e.g., 1400, 900, 500; 1900, 700, 1200; 1300, 100,1200; etc.).

Figure 59 illustrates the percentage of times that Q28a was either > or = or < the sum of Q28b and Q28c.

Table 87 shows the acreage by state for the various methods of gravity irrigation, save border irrigation. The appropriate methods used to sum the respondents' acre (***Q28b*** & ***Q28c***) are shown on the left side of the table. The inappropriate data columns included in summing gravity irrigation values (***Q28a***) are shown on the right side of the table. To put it in perspective, ***Q28a***, if it was to be included with the eight appropriate columns of data for totalizing acreage for all irrigation systems, would have been 2nd largest. Doing so would certainly skews things; districtwide the furrow/flood totals would have been 45% to high (**Table 87**).

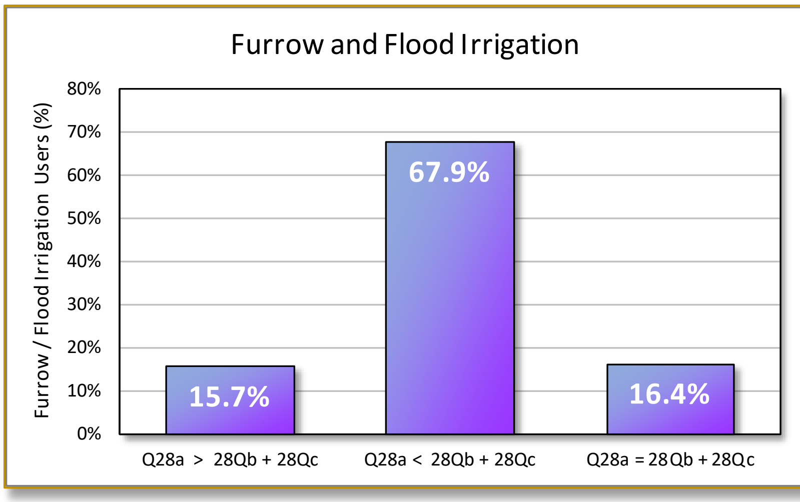


Figure 59. Relative value of respondent's values of Q28a to the sum of Q28b + Q28c

Table 87. Gravity Irrigation Systems & border component

Locale	Gravity Irrigation Systems					
	Appropriate Data for Tabulating Sums			Inappropriate Data for Tabulating Sums		
	Exclusively flood (acres) *(Q28b)*	Continuously furrow (acres) *(Q28c)*	TOTAL (acres) *(Q28b) + (Q28C)*	Alternate flood / furrow (acres) *(Q28a)*	Flood / furrow (acres) *(Q28a) + (Q28b) + (Q28C*	Amount flood / furrow would be over-estimated by (%)
Arkansas	142,482	236,859	379,341	229,425	608,766	60%
Louisiana	11,554	85,961	97,515	31,032	128,547	32%
Mississippi	32,995	183,637	216,632	66,070	282,702	30%
Missouri	3,610	42,192	45,802	6,830	52,632	15%
All 4 States	190,641	548,649	739,290	333,357	1,072,647	45%

Acres of Gravity Irrigation. In the mid-South, the gravity irrigation method is larger than pressurized methods of irrigation, both in terms of acres involved (85.4%) and the number of users (81.4%). Since researchers were interested in some of the special aspects of rice irrigation, data was segregated by rice and non-rice fields. This dichotomy led to data being collected under three groups: gravity (on all row crops), pressurized (on all row crops), and rice (on all irrigation methods).

Table 88. The three gravity irrigation methods used on field crops & portion that is border irrigation

Locale	Gravity Irrigation Systems – Field Crops				Border/TOTAL (%)
	Exclusively flood (acres) (***Q28b***)	Continuously furrow (acres) (***Q28c***)	Border (acres) (***Q30***)	TOTAL (acres)	
Arkansas	142,482	236,859	13,205	392,546	3.4%
Louisiana	11,554	85,961	2,287	99,802	2.3%
Mississippi	32,995	183,637	2,735	219,367	1.2%
Missouri	3,610	42,192	6,400	52,202	12.3%
All 4 States	190,641	548,649	24,627	763,917	3.2%

Border Irrigation (Row Crops). The *USBISR* lists 240,318 acres of rice irrigated using various forms of border irrigation. This represents 89% of the total irrigated rice acreage (the rice border methods were precision grade, contour levee and zero grade). In comparison, in 2015 only 3.2% of *field crops* were irrigated with border irrigation. Although, this reported percentage in 2015 field crop acreage appears small, there were indications that this value could be understating borders' use on field crops in the mid-South.

Question Q29, seen below, queries whether the interviewee had ever used border irrigation on field crops.

Have you ever used border irrigation for corn, cotton, grain sorghum, and/or soybeans?

Q29 ______
- Yes (1)
- No (2)
- Don't know (3)
- Refused (4)

Ninety-one people responded YES to this question (representing 20% of total respondents surveyed and 24% of that group that used some amount of non-rice gravity irrigation). Already alluded to, in response to question ***Q30***, the very next one in the survey, which queried for the number of these acres, just 60% of those formerly saying YES, they had used border irrigation on row crops, now reported zero acres. "Ever used" is probably an important phrase in the question. There were just ten questions within the *USBIS* questionnaire that actually were used in tally total irrigation acreage based by irrigation methods (***Acres***$_{IM}$). Only four of those ten were quantified with the statement "ever used."

Table 89 presents data on row crop border irrigation by users.

Table 89. Border irrigation of row crops based on users

Row crop border irrigation based on a user basis							
Locale	Total Responding YES			Number Responding YES and acreage data supplied			
	Yes	%, All in survey [A]	%, All gravity irrigators [B]	Yes + acreage amount >0 supplied N	Yes + acreage amount >0 supplied %	%, All in survey [A]	%, All gravity irrigators [B]
Arkansas	52	26%	30%	23	44%	12%	13%
Louisiana	8	9%	14%	6	75%	6%	10%
Mississippi	26	18%	21%	9	35%	6%	7%
Missouri	5	19%	28%	2	40%	8%	11%
All 4 States	91	20%	24%	40	44%	9%	11%

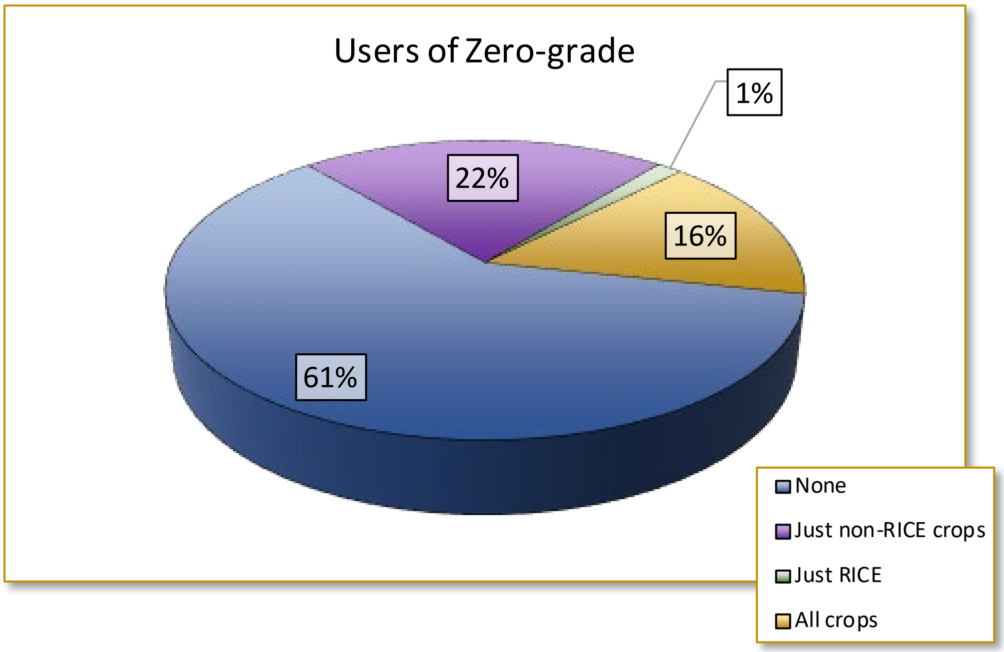
[A] 466.
[B] 376.

Another interesting factor about border irrigation on field crops, is that for the 10% or so of people using border irrigation in 2015, border irrigation represented over on third of all their gravity irrigation (**Table 90**).

Table 90. In field crops the proportion of border fields to all gravity irrigated fields

Locale	When Border is present, % it is of all gravity irrigation acreage	Exclusively flood & Continuously furrow fields		Border fields		N Border / N Exclusively flood & Continuously furrow (%)
		Avg. Acres	N	Avg. Acres	N	
Arkansas	37.7%	2,155	176	629	21	10.7%
Louisiana	31.5%	1,653	59	381	6	9.2%
Mississippi	19.9%	1,761	123	391	7	5.4%
Missouri	50.0%	2,545	18	3,200	2	10.0%
All 4 States	33.9%	1,966	376	684	36	8.7%

<u>Zero-slope.</u> As its name implies, zero-slope irrigation is a form of border irrigation that has neither main- or slide-slopes. One of the advantages of zero-slope is that it keeps water (whether from irrigation or rain) from bunching up at the bottom of the field. Thirty-nine percent of the farmers surveyed used some amount of zero-slope irrigation. The *USBISR* lists 240,318 acres of rice irrigated using various forms of border irrigation. This represents 89% of the total



15 Irrigation Best Management Practices (*IBMP*s)

A significant portion of the survey was dedicated to assessing a series of Irrigation Best Management Practices (IBMPs) or Irrigation Water Management Practices considered easily adopted into mid-south production practices. The involved IBMPs included: TWR, MIRI, storage reservoirs, surge flow, zero-grade, use of pivots and irrigation scheduling. The actual survey also included a question on computer size holes but was not able to be tabulated because of some reporting error. Additionally, information was gathered regarding the use of deep tillage and end blocking of furrow. The number of acres of each practice, respondents implementing the practices, the perceived benefit of the practice, were asked. Additionally, for each practice, why they adopted the practice was asked, conversely if they did not adopt the practice, they were provided a group of reasons for not adopting the practice. This approach was useful to assess what educational methods were most effective at instigating adoption.

15.1 Associated Energy Savings from *IBMP*s

Questions regarding various components of ***IBMP***s, including one concerning expected energy savings, were posed to the participants. There is special regard in this query level, as it offered one of the few quantitative measures of impact in the study.[23] The specific energy-saving parameter asked about was the change in pumping time stemming from the use of the practice (*"…by what percent did pumping time decrease [if any] as a result of the change?*). This was a wise choice of parameters to use in regards energy use as:

- It cuts across energy differences between situations (e.g., deep vs. shallow well, pivot vs. flood, etc.).
- It is an amount that farmers would readily know.

The average expected energy savings for all nine practices was 11.9%. However, in examining the data and the results, it was seen that most of the responses were skewed left. The value zero was reported 53% of the time (i.e., only 47% of the responses were net positive). Besides the calculated responses, there was an additional 32% that were "Don't know." It can be possible that the irrigators could be separated into two broad groups," those that could not coax a benefit" from the practice and those "who got the knack of it." Therefore, two means were calculated from the data: all data responses used ($\ddot{X}$) and a set where the zero responses were culled ($\ddot{X}_{no\ zeroes}$). This latter value would be given with the caveat that, once one has mastered the idiosyncrasies of the practice, these might be the obtained energy reductions. Figure 15 and table 14 show these results.

Figure 16 shows the histogram of the average of all nine practices. The frequency response of the Y-axis (normally the number of responses within a bin limit) has been converted to a relative value as there were various number of replies among the nine practices (from a low of 51 to a high of 194). Figure 17 is a composite view of all histograms together.

Table13 shows means of $\ddot{X}$ and $\ddot{X}_{no\ zeroes}$, sorted by $\ddot{X}$ mean values (highest to lowest). Zero-grade has the highest energy-saving value under both $\ddot{X}$ and $\ddot{X}_{no\ zeroes}$, calculation methods. The histogram of zero-grade, seen in figure 17, has the least amount of skewing. Also, of interest in table 13, is that for the three furrow-associated ***IBMP***s of TWR, storage reservoir, and MIRI, they remain fairly low (13-14%) using the $\ddot{X}$ calculation but are rated about 25-30% for "who have the knack of it."

[23] The other such interrogatory was the question concerning expected 2015 crop yields.

ca

Table 91. Anticipated energy savings from nine irrigation practices

Practice	Ẍ	$\ddot{X}_{no\ zeroes}$
Zero Grade	22.6%	30.4%
Tail water recovery	14.4%	26.4%
Storage Reservoir	13.8%	30.0%
Multi Inlet	13.4%	24.3%
Scheduling	12.7%	19.4%
Surge	10.5%	19.9%
End Blocking	9.5%	15.2%
Deep Tillage	6.2%	19.8%
Center Pivot	4.4%	20.6%

For rice, some additional information that could be described as ***IBMP***s related to water management was asked about in the Q103 series of questions and regarding scheduling in the Q104 series of questions. They will have been reported about in *Section 5.4 Rice*.

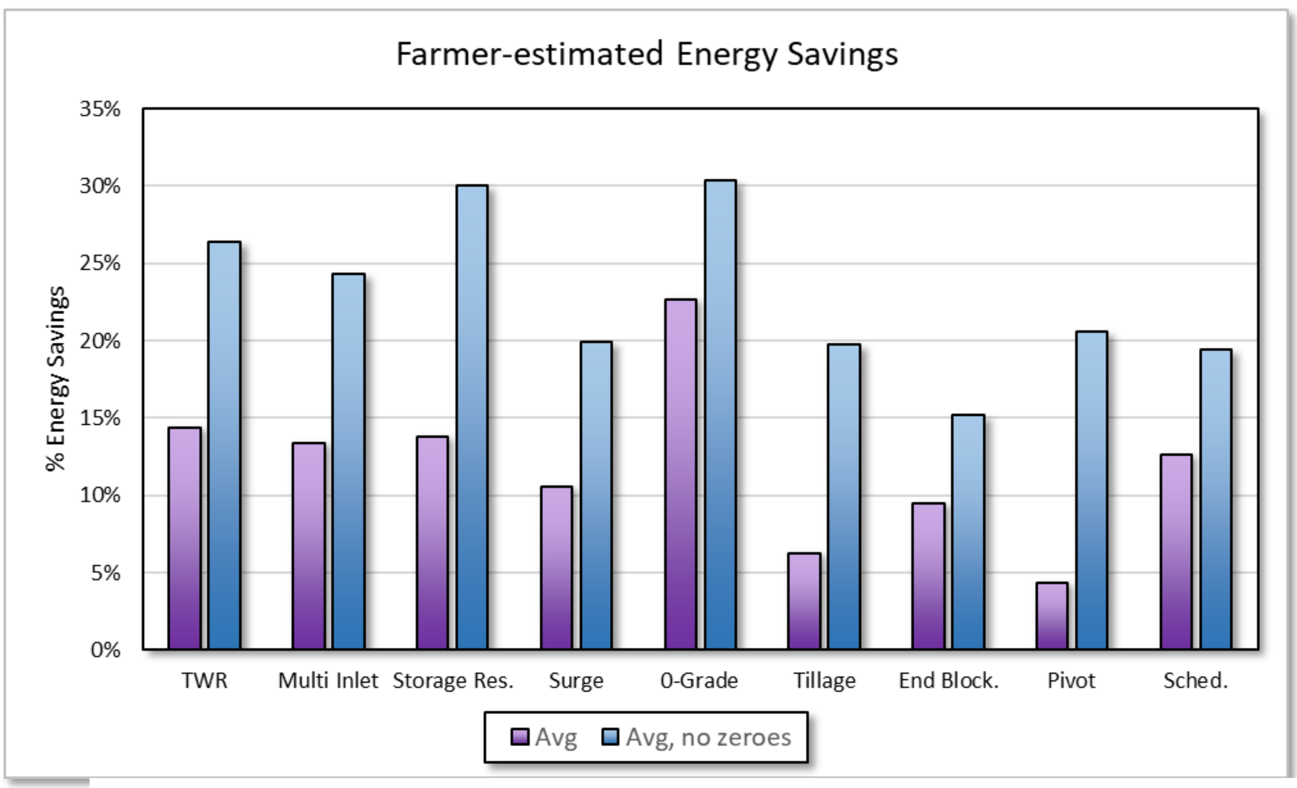


Figure 15. Estimated energy savings from various IBMPs for averages and averages with zeroes removed

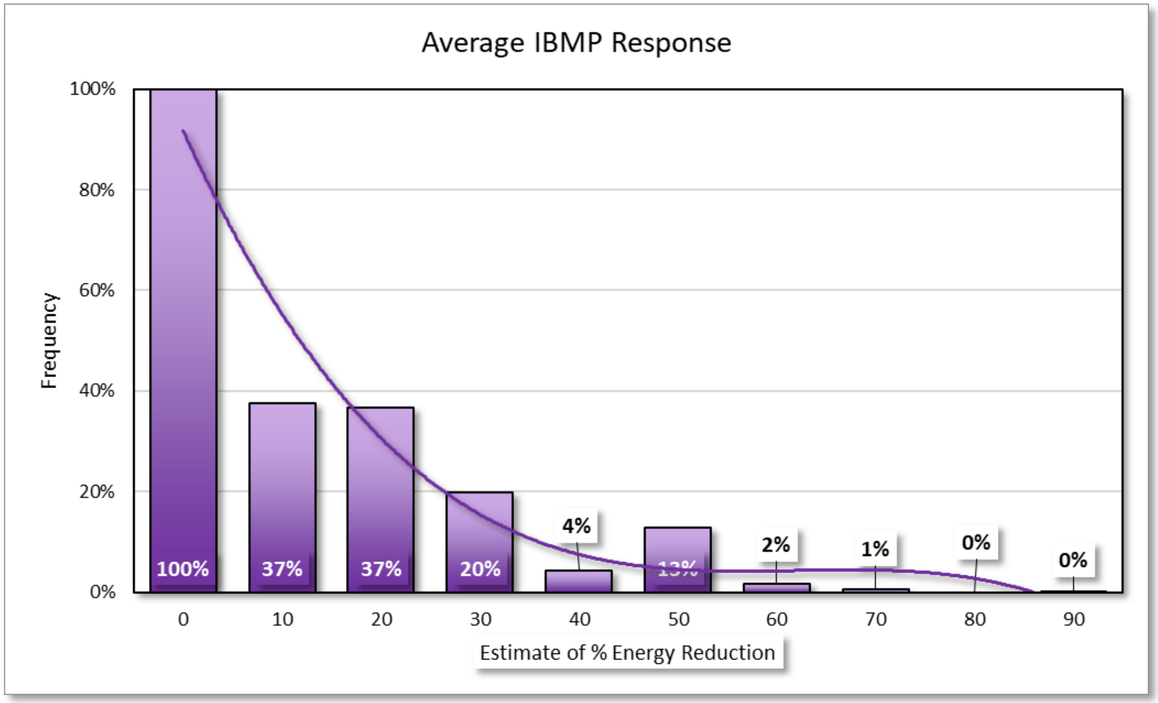


Figure 60. Average of nine *IBMP* histogram responses

Table 92. Expected energy savings from various IBMPs –total number of responses (zeroes, non-zeroes, & rebuffs) and average energy savings (both as reported and with zero responses removed)

Responses & Energy Savings	Irrigation Best Management Practices																	
	Tail water recovery		Multi Inlet		Storage Reservoir		Surge		Zero Grade		Deep Tillage		End Blocking		Center Pivot		Scheduling	
Total #s	119		180		100		74		51		194		90		151		95	
Refused		0		1		1		1		0		1		0		1		0
Don't Know		33		41		32		18		7		86		42		61		22
Zeroes	54		81		54		35		13		133		34		119		33	
% Zeroes		45%		45%		54%		47%		26%		60%		38%		79%		35%
Non-zeroes	65		99		46		39		38		61		56		32		62	
% Expected Energy Savings	Ẍ	Ẍ no zeroes	Ẍ	Ẍ no zeroes	Ẍ	Ẍ no zeroes	Ẍ	Ẍ no zeroes	Ẍ	Ẍ no zeroes	Ẍ	Ẍ no zeroes	Ẍ	Ẍ no zeroes	Ẍ	Ẍ no zeroes	Ẍ	Ẍ no zeroes
	14%	26%	13%	24%	14%	30%	11%	20%	23%	30%	6%	20%	10%	15%	4%	21%	13%	19%

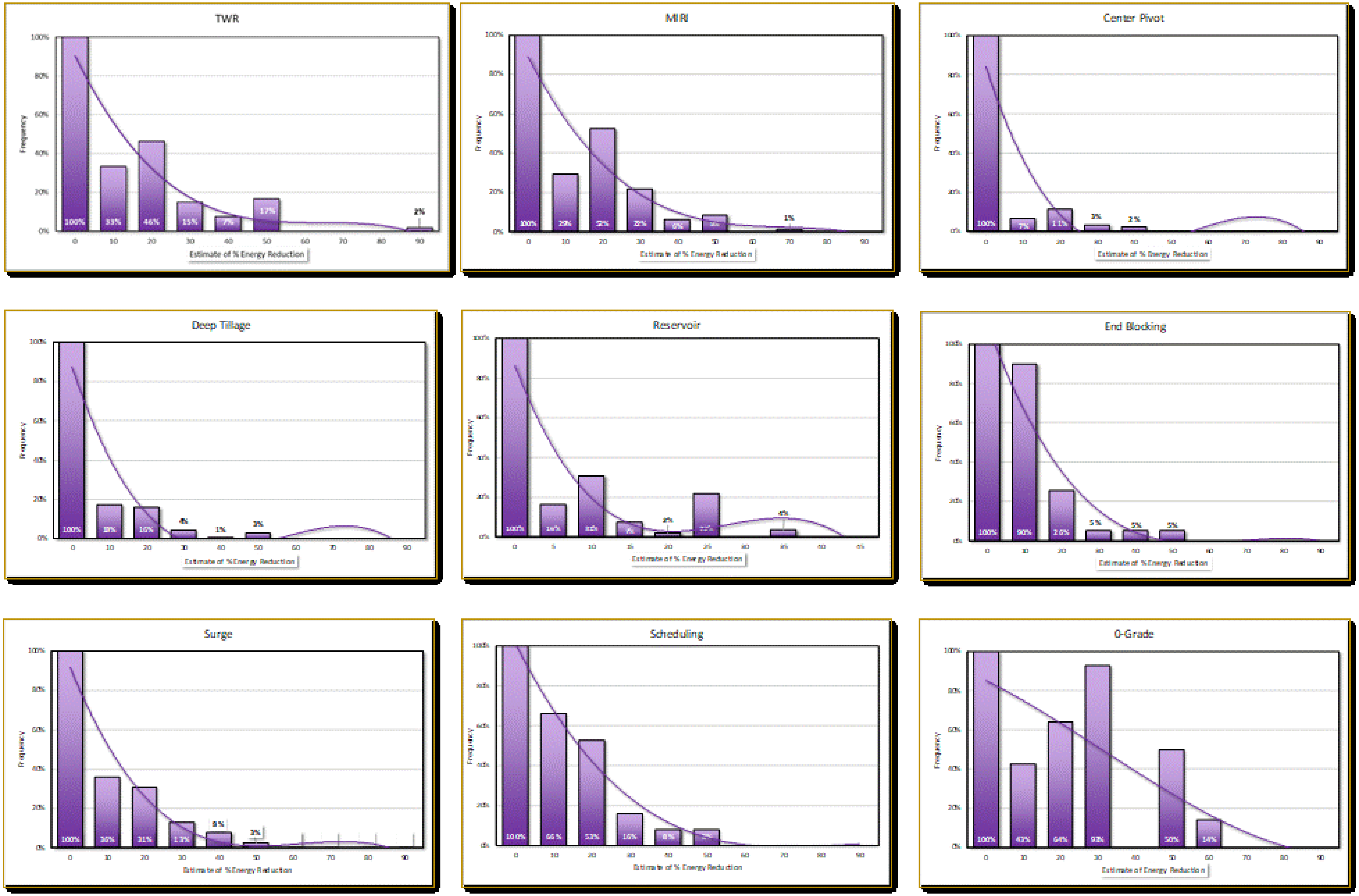


Figure 61. Histograms of expected energy savings for farmers for nine *IBMPs*, showing trends to be skewered to the left. Zero-grade (bottom, right image) was the least skewed response

15.2 Accumulated Adoption Curves

The survey collected information from farmers on the month/year they began using about a dozen different IBMPs:

Surge Flow	Q41	Q43_1
Pivot back to Furrow: $(P \rightarrow F)_1$ $(P \rightarrow F)_2$	Q57 Q67	Q58_1
Using Pivot	Q60 Q61	Q64_1
Soil Moisture Sensing	Q82_9	Q83_1

Tail Water Recovery [A]	Q19_1
Storage Reservoirs [A]	Q24_1
Computerized Hole Selection	Q38_1
Surge Flow	Q43_1
Pivot back to Furrow:	
	Q58_1
Using Pivot	Q64_1
Soil Moisture Sensing	Q83_1
ET gauges (Atmometer)	Q86_1
Computer Scheduling	Q88_1
Woodruff Irrigation Charts	Q90_1
Precision Leveling	Q49_1
Zero Grade	Q98_1
MIRI – contour	Q101_1
MIRI - precision	

Q57 Thinking about your acres that are currently using furrow irrigation, at any point in the past **(IN THE PAST)**, were you using pivot irrigation for those acres? **P → F** ☐ Yes (1) ☐ No (2) ☐ No furrow irrigation (3) ☐ Don't Know (4) ☐ Refused (5)

When did you start **(IN THE PAST)** to convert from pivot irrigation to furrow irrigation? **P → F**. **Q58_1** Year Q58_2 Month

Q59 On how many of your **# total acres** **(IN THE PAST)** have you replaced pivot irrigation with furrow irrigation? **P → F** ______ Don't Know (-1) Refused (-2)

Q67 Are you considering converting **(IN THE FUTURE)** any of your pivot irrigated acres to furrow irrigated in the future? **P → F** ☐ Yes (1) ☐ No (2) ☐ Prefer not to answer (3)

Q68 How many of your **# pivot irrigated acres** **(IN THE FUTURE)** are you considering converting to furrow irrigated? **P → F** ______ Don't Know (-1) Refused (-2)

Surge Flow	Q41	Q43_1
Pivot back to Furrow: (P → F)1 (P → F)2	Q57 Q67	Q58_1
Using Pivot	Q60 Q61	Q64_1
Soil Moisture Sensing	Q82_9	Q83_1

One IBMP that is both symbolic and formative to mid-South irrigation-- was the use of precision land formation. An interesting factor about the adoption of this irrigation BMP was that it began in the 1950s (LA), and ‘60s(AR) and ‘70s (MS) (Table 32), a period during which the vast portion of federal irrigation research funding was going to the arid west, and little to the mid-South.

Table 93. Earliest Year of Adoption of Precision Leveling, Average Year of Adoption, and number in AR, LA, MS, and MO

STATE	Earliest Adoption Year	Average Year of Practice Adoption	Number
Arkansas	**1960**	**1996**	**89**
Louisiana	**1955**	**1996**	**23**
Mississippi	**1970**	**1994**	**20**
Missouri	**1985**	**1995**	**4**
All 4 States	**1955**	**1,996**	**136**

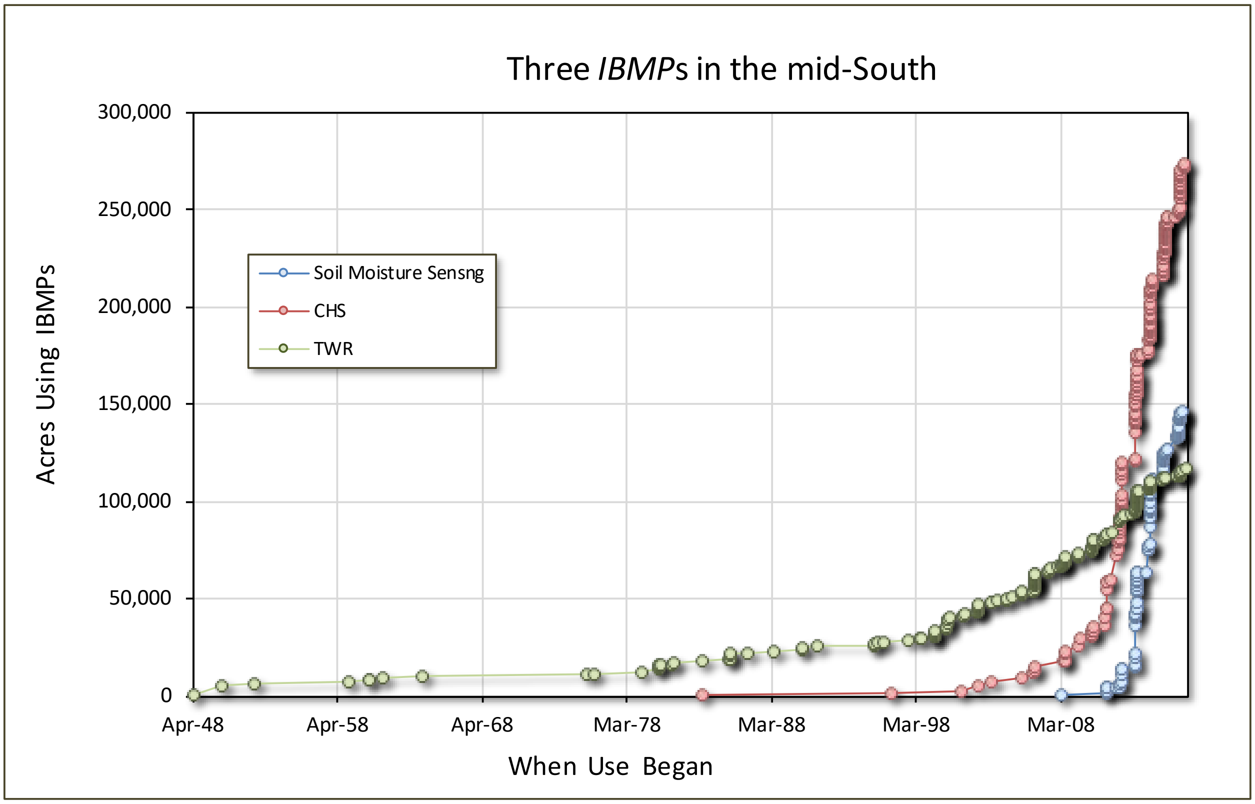


Figure 62. Adoption rate history of three *IBMP*s in the mid-South during different periods: early (TWR), mid (CHS), and late (SMS)

From the survey adoption history data was collected on: Tail Water use, Storage Reservoir use, computerized hole selection, surge flow, conversion of furrow to pivot (and vice versa), soil moisture sensing, atmometer use, computer scheduling, and use of Woodruff charts. Figure 1 shows the adoption history of computerized hole selection for poly-pipe. Collecting and publishing these data illustrates the inflection point of the joint agency, university and industry efforts that were occurring in the 2000 teens.

Several lines of questioning involved learning when farmers began using some of the ***IBMP***s being investigated in the survey. Collecting information on these adoption times data is important for the study of irrigation history in the mid-South. Some significant irrigation milestones that occurred and were to influence irrigation in the mid-South include use of center pivots (1960s), laser-guided land forming (1970s), surge flow (1980s), use of poly-pipe (1980s), weather data collection and irrigation scheduling (1980s), manual soil moisture sensors (1960s), automated soil moisture sensors (2000s), water capture and impoundment (tail water recovery [1970s] and storage reservoirs [2000s]), and GPS-guided land forming (2010s).

Table 33 lists some of the irrigation and agronomic management practices that were asked about in the survey. For some of these practices, information was both collected on <u>when started</u> and <u>acreage amount</u> of involved (B) – which affords us the most insight. In other cases, only data regarding acreage amount (A) was collected, while in still others, only the adoption commencement date (T) was collected.

Finally, for some other practices neither adoption time nor acreage amount information was collected; instead, the query regarding the practice might ask about another quantifier (e.g., “how many flow meters do you have?”), or if the practice was being done (e.g., “do you use rotor sprinklers?).

15.3 Storage Reservoirs

The question below, not included in the results of this survey, was put forth to the same group of irrigators regarding any previous knowledge they had of acquaintances practicing various IBMPs.

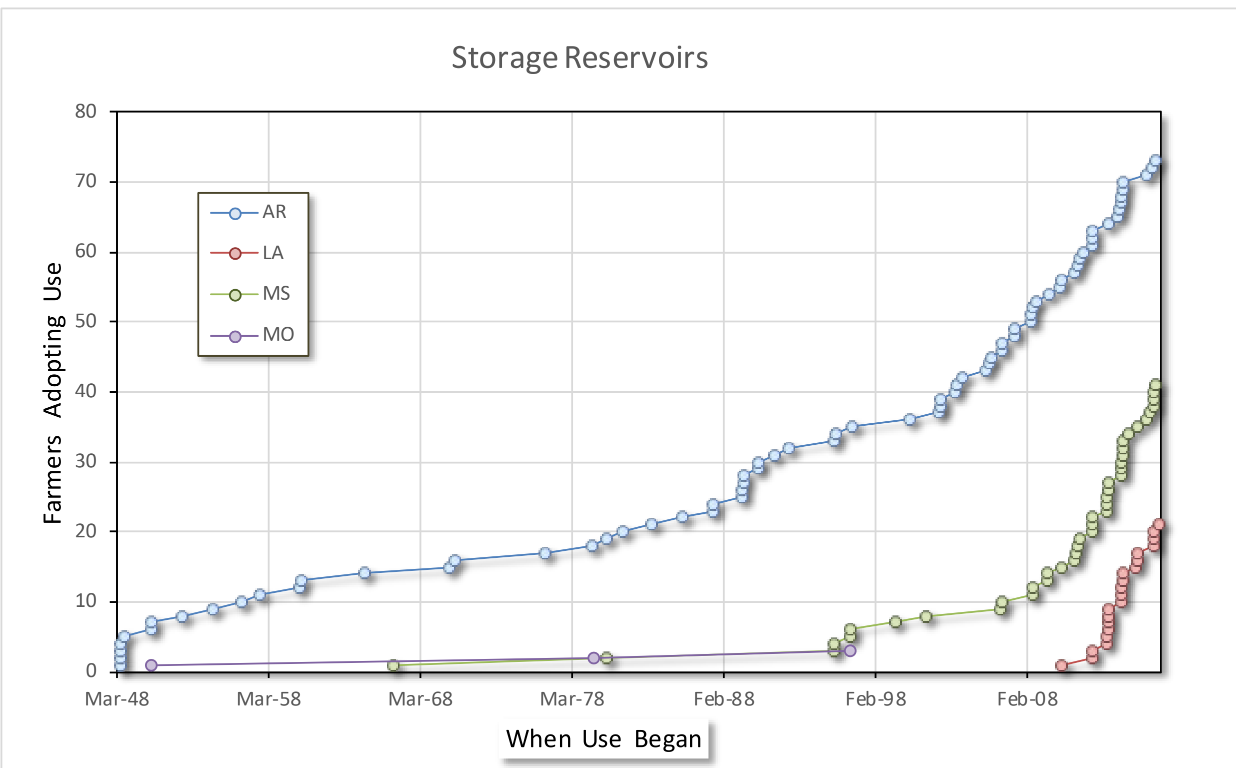


Figure 63. Adoption rate history of storage reservoir use in the mid-South

15.4 Tail Water Recovery

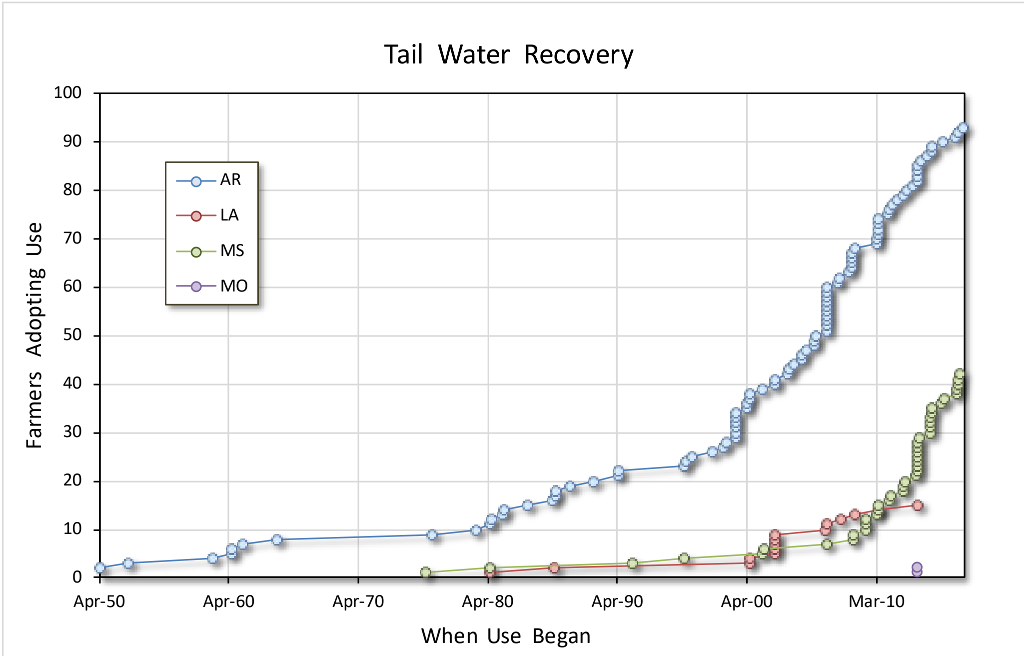


Figure 64. Adoption rate history of tail water recovery use by state in the mid-South

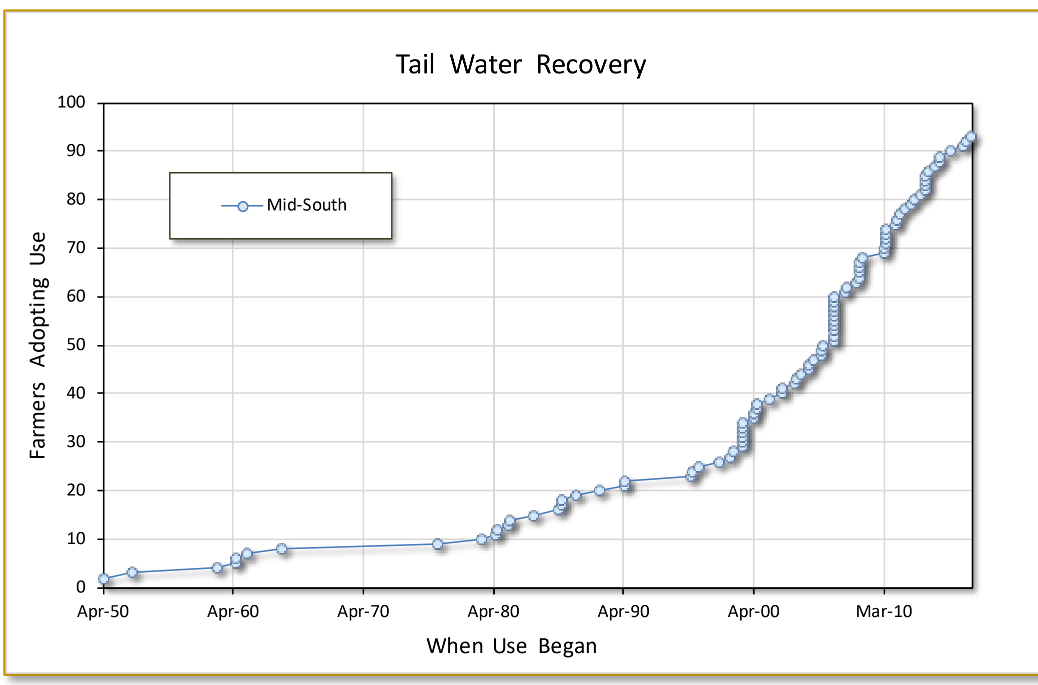


Figure 65. Numbers of farmers employing tail water recovery use in the mid-South

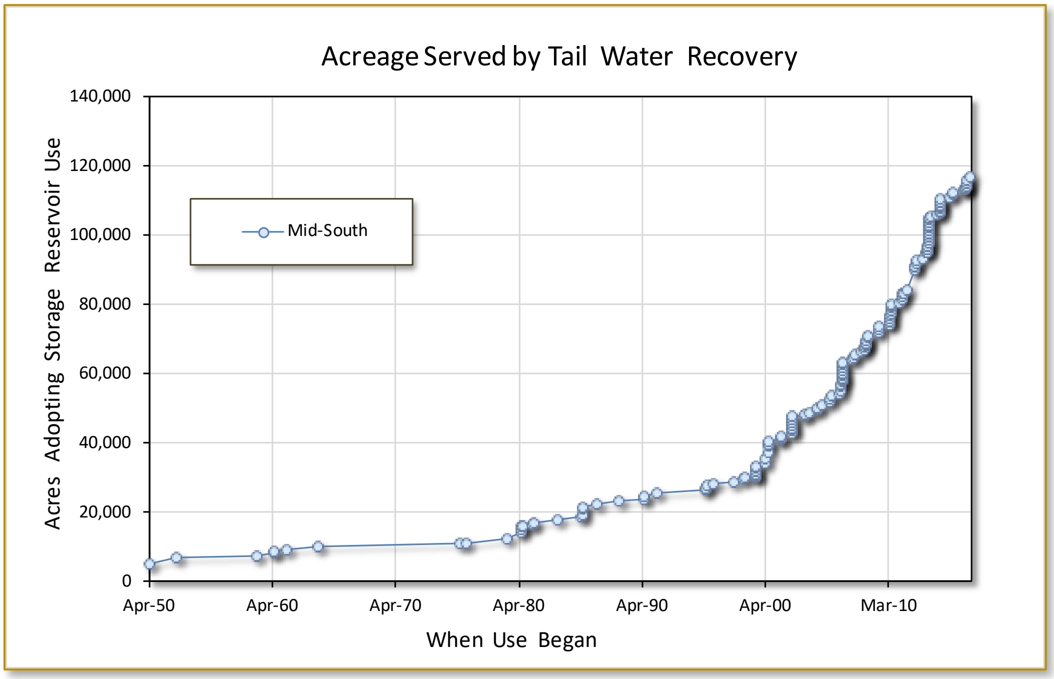


Figure 66. Adoption rate history of tail water recovery use in the mid-South

15.5 Computerized Hole Selection

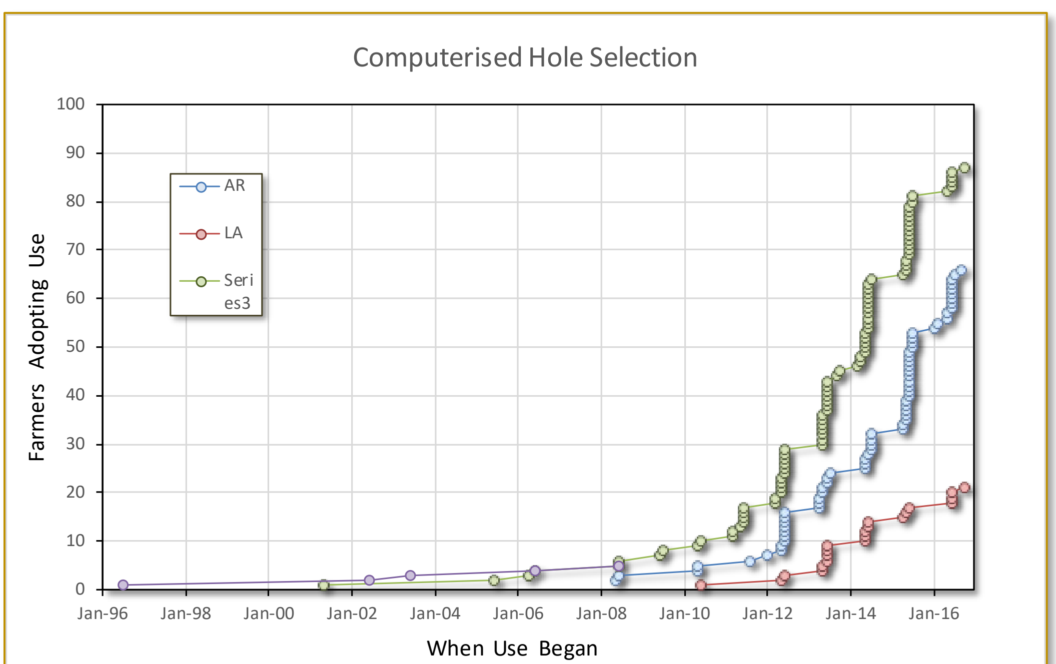


Figure 67. Adoption rate history of computerized hole selection by state in the mid-South

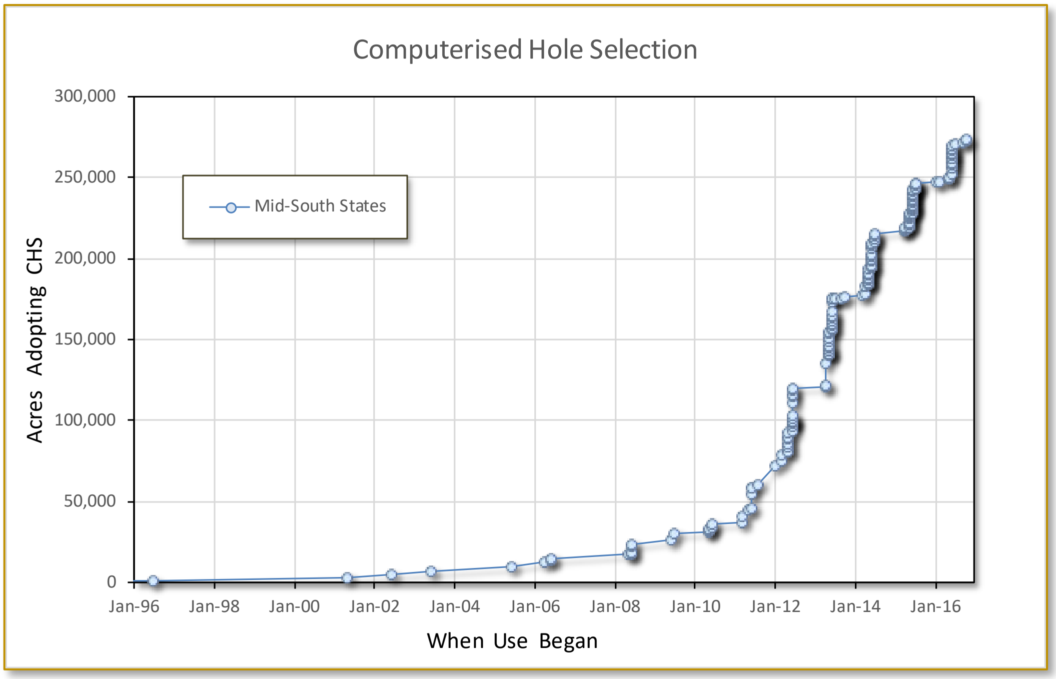


Figure 68. Adoption rate history of computerized hole selection in the mid-South

15.6 Surge Flow

Surge Irrigation is the use of an oscillating valve and programmable controller to advance water in on and off cycles for the purpose of improving the down furrow distribution uniformity in surface irrigation. **Table 94** shows the total area of respondents that answered the surge irrigation query. The total acres of furrow irrigated acres, acres of surge flow irrigation were then divided by the number of farms to obtain the acres per farm of furrow irrigated acres and surge irrigated acres per farm. Percent of adoption is reported as the number of participants that reported using surge irrigation. Adoption of surge irrigation valves appears to have increased dramatically between 2012 and 2015 compared to previous years (**Figure 69**). The highest adoption of surge flow irrigation is Missouri (31.2%) and Mississippi (25%) likely due to educational efforts in those states. Louisiana and Arkansas have lower adoption rates of 19.6% and 17.1% respectfully.

Table 94. The use of surge flow – total regional acreage, amount per farm, and % using

Region	TOTAL Area			Amount per Farm		Participants		
	Furrow	Surge	S/F %	Furrow	Surge	Furrow	Surge	S/F %
	------ acres ------		--- % ---	------ acres ------		--------- # ---------		--- % ---
Arkansas	236,859	9,957	4.2%	1,499	369	158	27	17.1%
Louisiana	85,961	3,005	3.5%	1,535	273	56	11	19.6%
Mississippi	183,637	10,030	5.5%	1,583	346	116	29	25.0%
Missouri	42,192	8,300	19.7%	2,637	1,660	16	5	31.3%
All 4 States	548,649	31,292	5.7%	1,586	435	346	72	20.8%

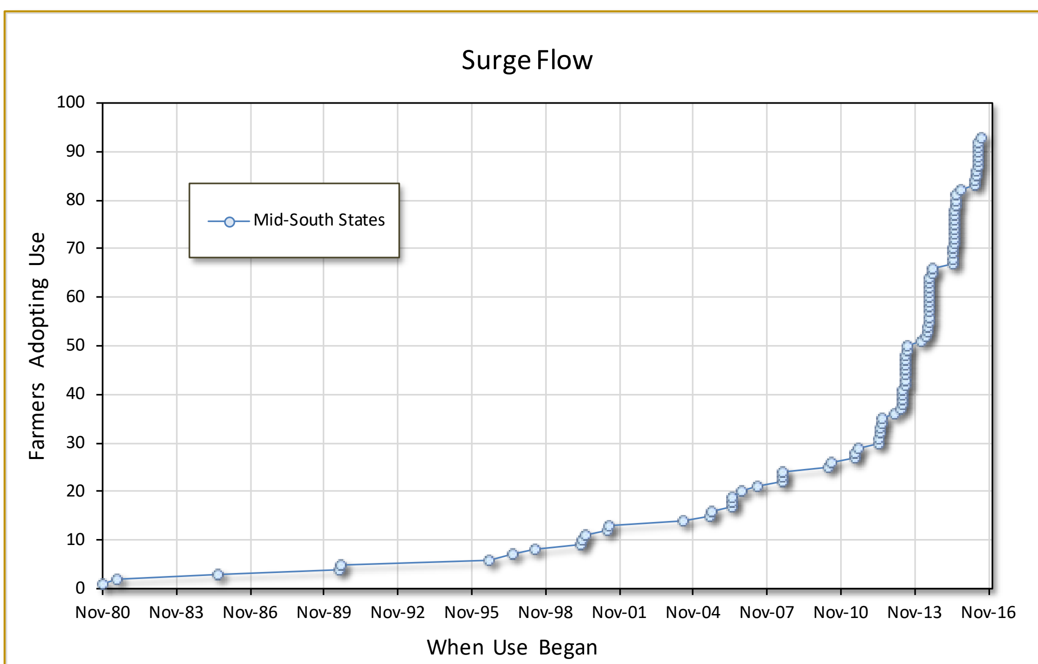


Figure 69. Adoption rate history of surge flow in the mid-South

15.7 Precision Leveling

Questions about precision levelling included when it was first adopted, the reason they starting using it and how they paid to implement it on their farming operation. They were also asked if they did not adopt precision levelling, why they chose not to adopt it.

Q49_1, Q49_2

When did you start using precision leveling?

Year? ______

Month? ______

Q50

What is the primary reason you started using precision leveling? Was it because...

- ʘ Government assistance was available to defer the cost (1)
- ʘ Irrigation water was limited (2)
- ʘ It improves drainage on my farms (3)
- ʘ It makes irrigation easier (4)
- ʘ It improved my profitability (5)
- ʘ I could afford it, because it became more economical to do (6)
- ʘ Other (7) (*Please specify*) ____________________
  - ʘ Don't Know (8)
  - ʘ Refused (9)

Q51

Did you raise money for precision leveling?

- ʘ Yes (1) [Check all that apply]
  - Q51_1 ☐ Reinvestment of farm profits
  - Q51_2 ☐ Bank loan
  - Q51_3 ☐ Federal program cost share
  - Q51_4 ☐ Other
    - Q51_4_other (Please specify) ____________________
- ʘ No (2)
- ʘ Not Sure (3)
- ʘ Refused (4)

Q52

What is primary the reason you are not using precision leveling?

- ʘ Was not aware of precision leveling (1)
- ʘ Don't know how to use it (2)
- ʘ Takes too much time to implement (3)
- ʘ Groundwater is adequate (4) ☐ Surface water is adequate (5)
- ʘ Rental agreement does not allow for irrigation investment (6)
- ʘ Crop prices too low (7)
- ʘ Fuel, labor, and equipment costs too high (8)
- ʘ Would like to use the system, but unsure how to get started (9)
- ʘ It doesn't work on my farm (10)
- ʘ Other (11) Q52_other (Please specify) ____________________
- ʘ Don't Know (12)
- ʘ Refused (13)

Text Box 16. Survey questions Q49-52 re: precision leveling – when, why, funding, & why not

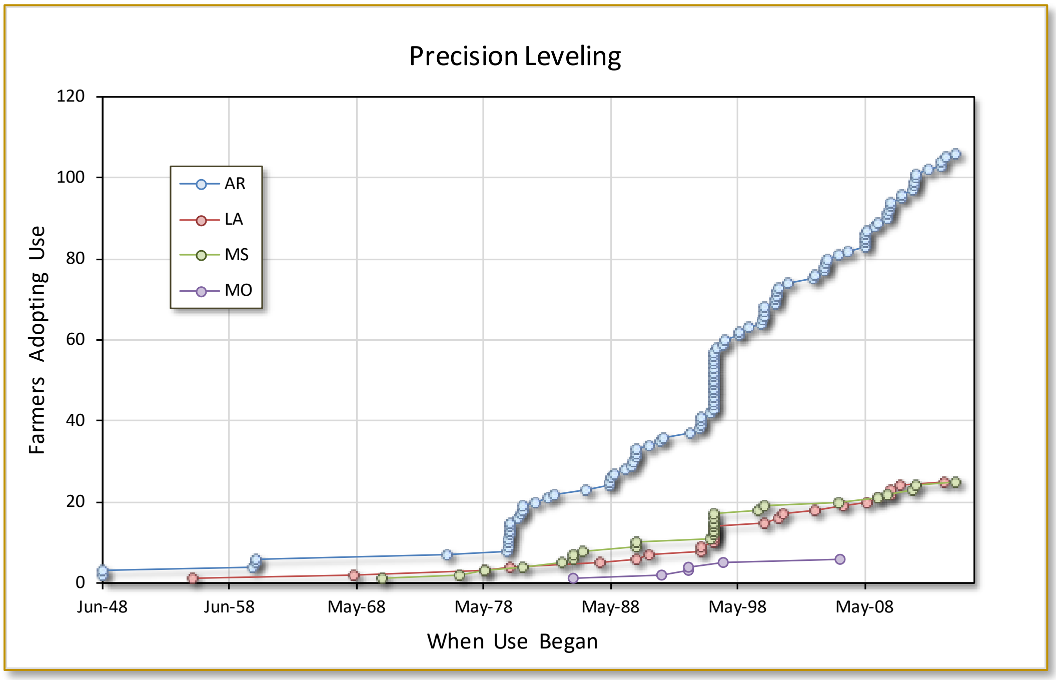


Figure 70. Adoption rate history of precision leveling by state in the mid-South

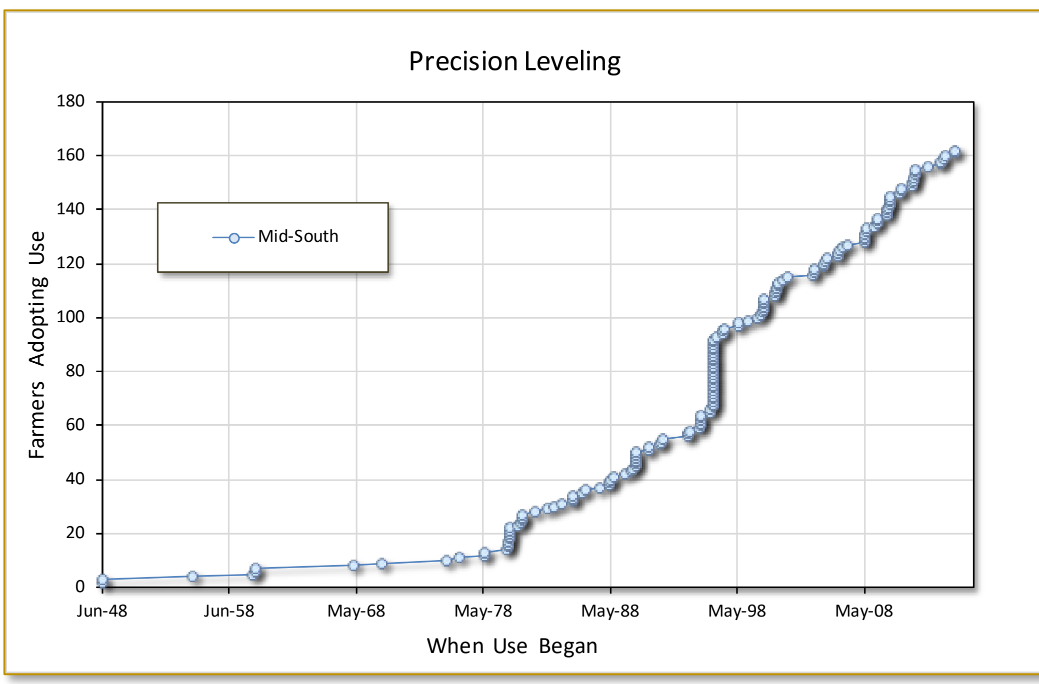


Figure 71. Adoption rate history of precision leveling in the mid-South

15.8 Zero Grade

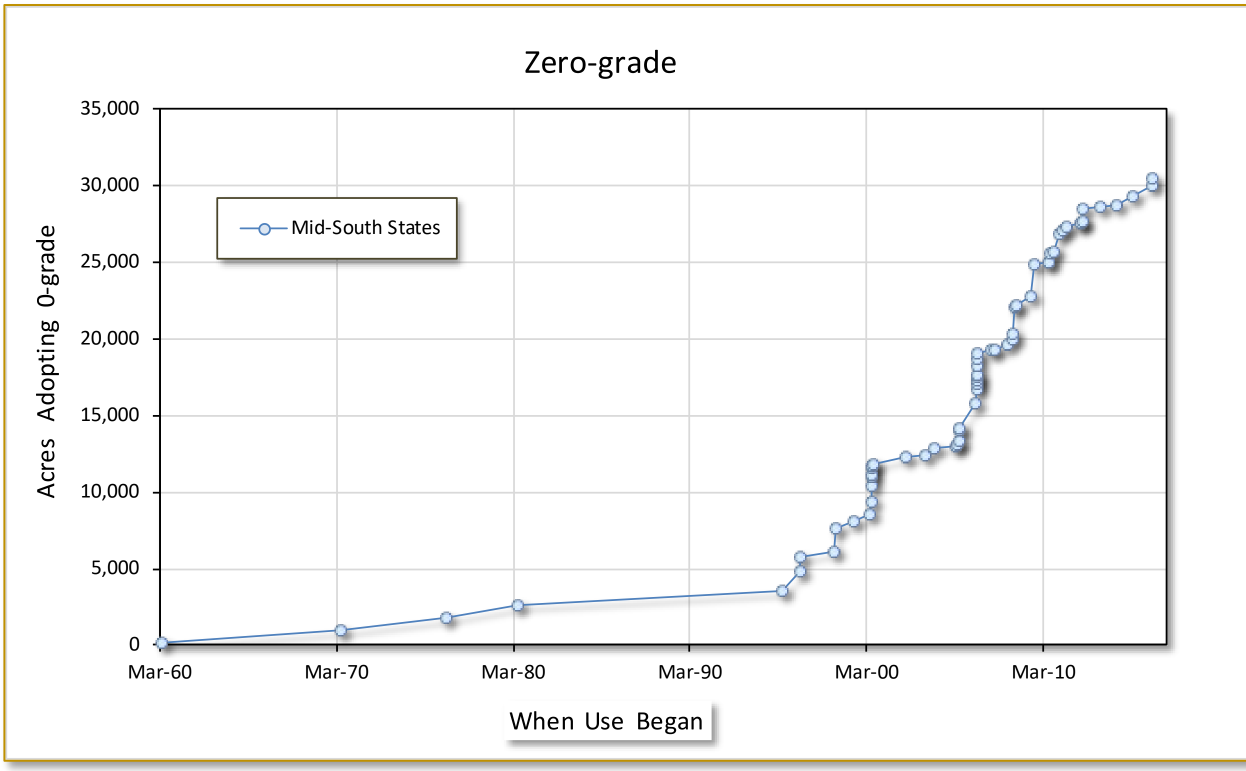


Figure 72. Adoption rate history of Zero-grade in the mid-South

Q98_1, Q98_2
When did you start using zero grade?
Year? ______
Month? ______

How was money raised for zero grade?
ʘ Yes (1) [Check all that apply]
Q99_1 ☐ Paid cash
Q99_2 ☐ Bank loan
Q99_3 ☐ Federal program cost share such as NRCS
Q99_4 ☐ State tax credit program
Q99_5 ☐ Other
Q99_5_other (Please specify) ____________________
ʘ No (2)
ʘ Not Sure (3)
ʘ Refused (4)
Refused (-2)

Text Box 17. Survey question Q98 re: precision leveling – when & funding

Q97_6c
How many of your total irrigated acres that are zero grade are continuous rice?
Acres? ______
Don't Know (-1)
Refused (-2)

Text Box 18. Survey questions Q97_6c re: Amount of zero-grade land is continuous rice

Border		0-Slope	
RICE	FIELD CROPS	RICE	FIELD CROPS
240,318	24,627	---	---
90.7%	9.3%	40.8% [A]	59.2% [B]

[A] Average calculation from two methods with values of 35.5% and 46.0%.

[B] Average calculation from two methods with values of 54.0% and 64.5%.

15.9 Multi-Inlet on Rice (MIRI)

The method of applying irrigation water to rice has changed remarkably in the last twenty years. Formerly, the most common method was by stair-step cascading. With this method water was pumped into the top paddock and on filling it up, water would then begin spilling over to the downstream adjacent paddock, and so on. One of the biggest problems associated with it is that there is no freeboard and paddies are always full. Thus, the method is poor at rainfall capture.

The multi-inlet application method uses conveyance pipeline, such as gated pipe or Polypipe, to bypass the need to cascade water from paddock to paddock. Using this method, irrigation water can be applied to contour levee (CL), precision grade (PG), and zero-slope fields. Extension programs in the mid-South, led primarily by Mississippi State and Arkansas Universities, developed the moniker MIRI (Multi-Inlet Rice Irrigation) to refer to this method of water application to rice.

The data gathered from the ***Q97*** series of questions, among assorted items, included the acreage amounts for CL and PG (***Q97_1*** and ***Q97_2***, seen earlier), as well as, the amount each of these methods employed MIRI (c.f., Text Box 14). For both methods, 55.4% of the combined CL and PG acreage of 217,486 acres was using MIRI. MIRI use was 80% in CL and 48% in PG (figure xxx).

Q97_6a

How many of your total irrigated acres that are contour levee fields use Multiple Inlet Rice Irrigation?

Acres? ______

Don't Know (-1)

Refused (-2)

Q97_6b

How many of your total irrigated acres that are precision grade fields use Multiple Inlet Rice Irrigation? Acres?

______

Don't Know (-1)

Refused (-2)

Text Box 14. Survey question series Q97 re: participant's acreage using MIRI

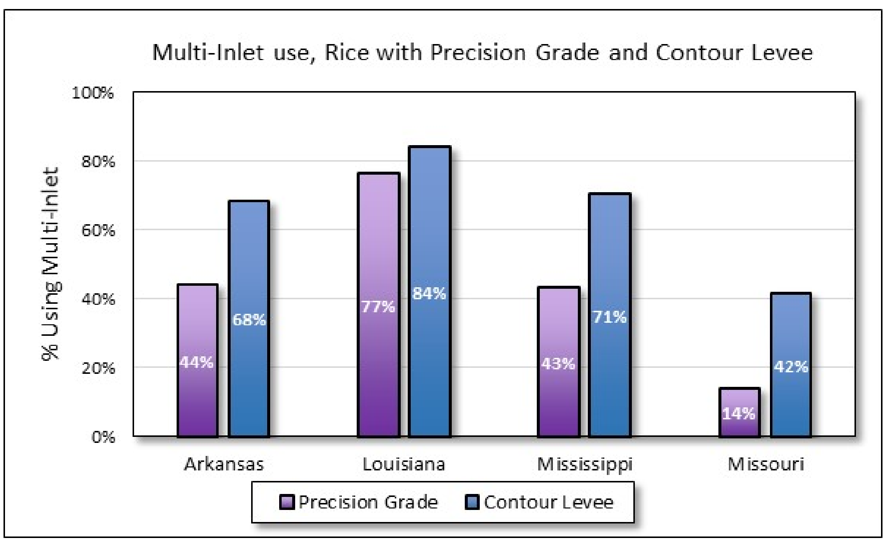


Figure 73. MIRI use in precision grade and contour levee rice

Q100_1, Q100_2

When did you start using multiple-inlet rice irrigation?

Year? ______

Month? ______

Q101

What is the primary reason you started using Multiple Inlet Rice Irrigation on your farm?

- O Profit allowed for new investment in technology (1)
- O Experienced water shortage on farm, needed to increase capacity (2)
- O Heard about this technology from a neighbor (3)
- O Learned about this technology at an Extension meeting (4)
- O Learned about this technology from an industry meeting (5)
- O I wanted to reduce input costs (6)
- O I tried it on my farm and saw the benefit (7)
- O Other (8)
  - Q101_other (Please specify) ____________________
- O Don't Know (9)
- O Refused (10)

Q102

O What is the primary reason you are not using Multiple Inlet Rice Irrigation on your farm?

- O Was not aware of multiple inlet rice (1
- O Don't know how to use it (2)
- O Takes too much time to implement (3)
- O Groundwater is adequate (4)
- O Surface water is adequate (5)
- O Rental agreement does not allow for irrigation investment (6)
- O Crop prices too low (7)
- O Fuel, labor, and equipment costs too high (8)
- O Damage to pipe during season is too much to keep repaired (9)
- O It doesn't work on my farm (10)
- O Would like to use the system, but unsure how to get started (11)
- O Other (12)
  - Q102_other (Please specify) ____________________
- O Don't Know (13)
- O Refused (14)
  - Refused (-2)

Text Box 15. Survey questions Q100-102 re: MIRI – when, why, & why not

15.10 Irrigation Scheduling

The question below, not included in the results of this survey, was put forth to the same group of irrigators regarding any previous knowledge they had of acquaintances practicing various IBMPs.

Table 95. Irrigation scheduling methods used by the participants

Location	Routine scheduling	Probe or feel	Watch neighbors	Woodruff charts	Computerized scheduler	ET or Atmometer	Canopy **temp**	Soil Moisture Sensors
Arkansas	33.8%	24.2%	8.1%	1.5%	6.1%	3.0%	0.0%	9.1%
Louisiana	23.9%	17.9%	0.0%	0.0%	0.0%	0.0%	0.0%	13.4%
Mississippi	19.7%	18.4%	4.1%	0.7%	3.4%	2.7%	0.7%	49.0%
Missouri	38.5%	34.6%	7.7%	0.0%	3.8%	3.8%	3.8%	15.4%
All 4 States	27.9%	21.9%	5.5%	0.9%	4.1%	2.5%	0.5%	23.5%

Table 96. The anticipated yields & sample size for irrigators using, or not using, soil moisture sensors

Locale	Corn		Soybean		Rice		Cotton	
	Use soil moisture sensors		Use soil moisture sensors		Use soil moisture sensors		Use soil moisture sensors	
	YES	NO	YES	NO	YES	NO	YES	NO
	---------------------------- bu/acre ----------------------------						----- lbs/acre ----	
Arkansas	196.5	187.2	58.9	55.4	175.8	179.6	1,291.0	1,250.9
	10	96	18	161	13	120	5	22
Louisiana	186.0	177.2	58.1	65.7	175.0	153.5	1,300.0	1,100.0
	7	41	9	45	2	10	4	10
Mississippi	193.3	181.0	60.2	55.0	175.4	173.4	1,288.9	1,200.0
	52	35	63	60	14	17	27	13
Missouri	211.3	201.1	53.3	59.3	---	176.7	1,316.7	1,091.7
	4	19	4	21	---	6	3	6
All 4 states	194.0	185.3	59.5	57.2	175.5	177.1	1,292.4	1,189.6
	73	191	94	287	29	153	39	51

Table 97. The anticipated yields & sample size for irrigators using, or not using, computer scheduling

Locale	Corn		Soybean		Rice		Cotton	
	Use CS		Use CS		Use CS		Use CS	
	YES	NO	YES	NO	YES	NO	YES	NO
	---------------------------- bu/acre ----------------------------						----- lbs/acre ----	
Arkansas	195.6	187.4	52.3	55.9	181.1	179.1	1,200.0	1,263.0
	9	97	11	168	9	124	2	25
Louisiana	NA	178.5	NA	64.4	NA	157.1	NA	1,157.1
	0	48	0	54	0	12	0	14
Mississippi	168.8	189.3	53.8	57.8	NA	174.3	1,300.0	1,259.0
	4	83	4	119	0	31	1	39
Missouri	200.0	203.0	73.0	57.8	NA	176.7	NA	1,166.7
	1	22	1	24	0	6	0	9
All 4 states	188.2	187.7	53.9	57.9	181.1	176.6	1,233.3	1,234.2
	14	250	16	365	9	173	3	87

Table 98. The anticipated yields & sample size for irrigators using, or not using, Woodruff graphs

Locale	Corn		Soybean		Rice		Cotton	
	Use WC		Use WC		Use WC		Use WC	
	YES	NO	YES	NO	YES	NO	YES	NO
	---------------------------- bu/acre ----------------------------						----- lbs/acre ----	
Arkansas	190.0	188.0	50.0	55.8	177.5	179.2	1,200.0	1,260.6
	2	104	2	177	2	131	1	26
Louisiana	#DIV/0!	178.5	NA	64.4	NA	157.1	NA	1,157.1
	0	48	0	54	0	12	0	14
Mississippi	200.0	188.2	60.0	57.6	200.0	173.4	1,200.0	1,261.5
	1	86	1	122	1	30	1	39
Missouri	NA	202.8	NA	58.4	NA	176.7	NA	1,166.7
	0	23	0	25	0	6	0	9
All 4 states	193.3	187.6	53.3	57.8	185.0	176.7	1,200.0	1,234.9
	3	261	3	378	3	179	2	88

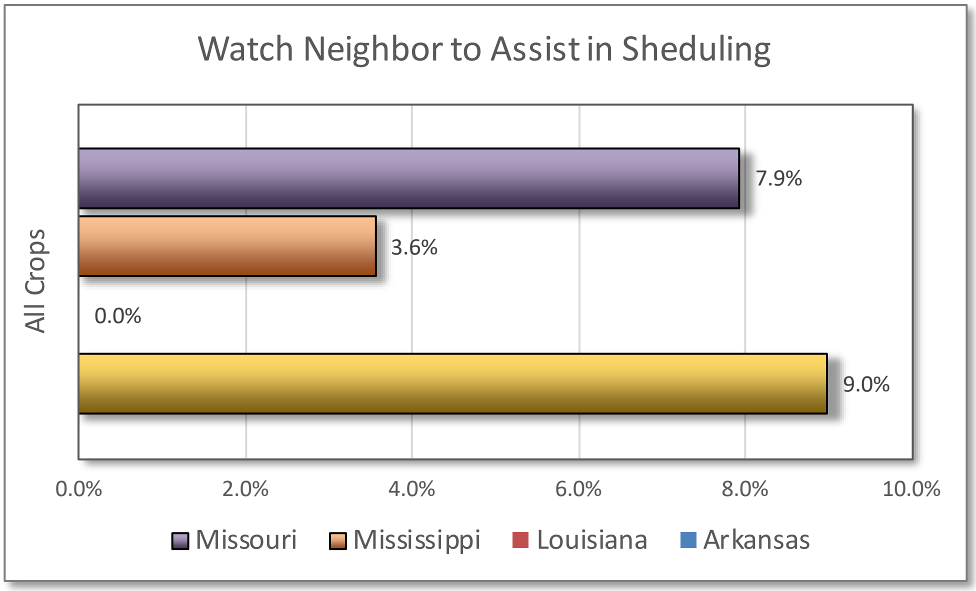

Watch Neighbor to Assist in Sheduling
All Crops
7.9%
3.6%
0.0%
9.0%
0.0%
2.0%
4.0%
6.0%
8.0%
10.0%
Missouri
Mississippi
Louisiana
Arkansas

Table 99. The anticipated yields & sample size for irrigators using, or not using, routine scheduling

Locale	Corn		Soybean		Rice		Cotton	
	Use routine		Use routine		Use routine		Use routine	
	YES	NO	YES	NO	YES	NO	YES	NO
	---------------------------- bu/acre ----------------------------						----- lbs/acre ----	
Arkansas	193.3	184.5	58.3	54.4	187.0	175.6	1,287.5	1,235.0
	43	63	60	119	42	91	12	15
Louisiana	177.5	178.8	69.5	62.5	190.0	146.1	1,100.0	1,166.7
	12	36	15	39	3	9	2	12
Mississippi	193.8	187.1	57.5	57.7	154.3	180.1	1,375.0	1,247.2
	16	71	26	97	7	24	4	36
Missouri	191.9	208.7	57.9	58.6	160.0	185.0	1,033.3	1,233.3
	8	15	9	16	2	4	3	6
All 4 states	190.8	186.4	59.6	57.0	181.9	174.7	1,250.0	1,229.3
	79	185	110	271	54	128	21	69

Table 100. The anticipated yields & sample size for irrigators using, or not using, probe or feel

Locale	Corn		Soybean		Rice		Cotton	
	Use feel		Use feel		Use feel		Use feel	
	YES	NO	YES	NO	YES	NO	YES	NO
	---------------------------- bu/acre ----------------------------						----- lbs/acre ----	
Arkansas	178.0	191.2	57.5	55.2	179.1	179.2	1,175.0	1,272.8
	25	81	40	139	34	99	4	23
Louisiana	198.0	174.0	73.8	62.8	NA	157.1	1,220.0	1,122.2
	9	39	8	46	0	12	5	9
Mississippi	185.9	188.9	60.3	57.2	150.0	175.1	1,320.0	1,251.4
	17	70	20	103	1	30	5	35
Missouri	205.8	201.8	57.3	58.9	160.0	185.0	500.0	1,250.0
	6	17	8	17	2	4	1	8
All 4 states	186.4	188.0	59.9	57.2	177.3	176.7	1,193.3	1,242.3
	57	207	76	305	37	145	15	75

Table 101. The anticipated yields & sample size for irrigators using, or not using, watching neighbors

Locale	Corn		Soybean		Rice		Cotton	
	Use soil moisture sensors		Use soil moisture sensors		Use soil moisture sensors		Use soil moisture sensors	
	YES	NO	YES	NO	YES	NO	YES	NO
	----------------------------- bu/acre				-----------------------------		----- lbs/acre ----	
Arkansas	196.5	187.2	58.9	55.4	175.8	179.6	1,291.0	1,250.9
	10	96	18	161	13	120	5	22
Louisiana	186.0	177.2	58.1	65.7	175.0	153.5	1,300.0	1,100.0
	7	41	9	45	2	10	4	10
Mississippi	193.3	181.0	60.2	55.0	175.4	173.4	1,288.9	1,200.0
	52	35	63	60	14	17	27	13
Missouri	211.3	201.1	53.3	59.3	---	176.7	1,316.7	1,091.7
	4	19	4	21	---	6	3	6
All 4 states	194.0	185.3	59.5	57.2	175.5	177.1	1,292.4	1,189.6
	73	191	94	287	29	153	39	51

Table 102. Yield differences between Sensor Users and non-Sensor Users in the mid-South

Tools Used for Irrigation Scheduling		CROP					
		Corn		Soybean		Cotton	
	Types of Sensors Used	Yield (bu/acre)	n	Yield (bu/acre)	n	Yield (lbs/acre)	n
Sensors Used	AquaSpy Sensor Brand	201.9	8	63.0	11	1,272	7
	Data logger Sensor Brand	---	---	65.0	1	---	---
	Ermish Sensor Brand	180.0	1	40.0	1	---	---
	Gyser Sensor Brand	---	---	50.0	1	---	---
	High Yield Ag Sensor Brand	196.7	3	60.0	3	1,400	1
	John Deere Sensor Brand	200.0	3	65.0	3	1,283	3
	King Sensor Brand	192.0	5	62.7	7	1,375	2
	Micrometer Sensor Brand	190.0	2	50.0	3	1,200	1
	Smart Farm Sensor Brand	230.0	1	80.0	1	1,500	1

Syntec Sensor Brand	190.0	1	67.5	2	---	---
University of Arkansas Sensor Brand	185.0	1	55.0	2	---	---
Wagnet Co Sensor Brand	---	---	62.0	1	---	---
Watermark Sensor Brand	201.4	7	63.1	8	1,320	5
Known Brands of Sensors	197.1	31	61.5	44	1,310	20
Unknown Brands of Sensors	190.8	41	57.7	50	1,274	19
Known & Unknown Brands of Sensors	193.5	72	59.5	94	1,292	39
% of irrigators using sensors	27.4%		24.6%		43.3%	
No Sensors Used	185.3	191	57.2	288	1,190	51
Difference in Yield (Sensor users – Non-sensor users)	8.2 bu/acre		2.3 bu/acre		102 lbs/acre	

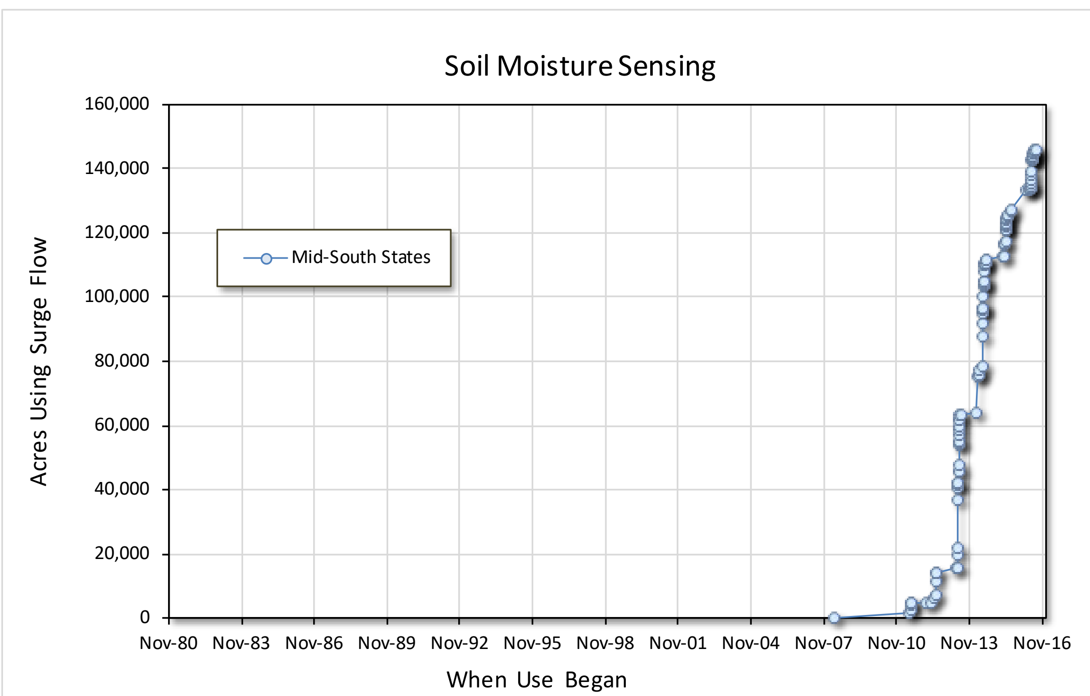


Figure 74. Adoption rate history of soil moisture sensing in the mid-South

6.3 Factors in IBMP Adoption

The question below, not included in the results of this survey, was put forth to the same group of irrigators regarding any previous knowledge they had of acquaintances practicing various IBMPs.

I'm going to read a list of practices. Please tell me if one or more of your close family members, friends or neighbor producers has used this practice in the past 10 years? [Check all that apply] Yes (1) No (2) Not Sure (3) Refused (4)

Q133_01 Center Pivot
Q133_02 Tail-water recovery system
Q133_03 Storage reservoir
Q133_04 Computerized hole selection (i.e. PHAUCET or Pipe Planner)
Q133_05 Surge irrigation
Q133_06 Flow meters on the wells
Q133_07 Precision leveling
Q133_08 Zero grade leveling
Q133_09 End blocking, cutback irrigation, or furrow diking
Q133_10 Irrigation scheduling methods such as computerized scheduler, Soil moisture sensors, ET, or Atmometer
Q133_11 Multiple-inlet rice irrigation
Q133_12 Alternate wetting and drying for rice irrigation

16 Conclusions

This work representing the 2015 crop year was undertaken to gather information on current irrigation practices in four mid-South states: Arkansas, Louisiana, Mississippi, and Missouri. The study was, funded with support from the United Soybean Board (USB) and the Mid-South Soybean board and carried out by extension staff in agricultural engineering and agronomy from each of the states' land grant universities. There were 8,572 contacted with a total of 466 completed phone interviews of irrigators in the region with a margin of error of 4.6%. It is believed to be the most extensive survey completed of irrigation practices for any region in the world. Main conclusions are as follows,

- In general, irrigators adjacent or near the northern reaches of the Mississippi River on the western side were not as concerned about shortage problems. The only exception for this was Cape Girardeau County in Missouri; it should be noted much of this county lies outside the range of the Mississippi River's delta. Growers on the river's eastern side (they all were in Mississippi), had mild levels of concern. In Arkansas, concerns of the irrigators about their state water shortage appeared to increase both in the downstream direction and, laterally, in distance from the river. The survey asked farmers to scale their feelings on groundwater shortages, both on their own farm and for the state at large. A scale of 1 to 5 was used, with 1 meaning 'no problem' and 5 meaning 'severe problem'. Respondents appeared more optimistic regarding their own individual farm than they did for the state. However, farmers appeared very reluctant to answer the question when it regarded their own farm (a response on concern level for the state was almost five times as forthcoming.
- Several questions regarding water meters were asked of the participants. First, a general interrogatory, was asked if the participant owned any flow meters. 95.7% of the survey participants responded. Then two follow up questions inquired on the number of permanent-in-place and portable meters that were owned. Over four fifths (42.4%) of the growers indicated that they had a flow meter; however, differences by state ranged greatly, with Missouri, the least, having none and Mississippi, the highest, having 70.5%. In every case, for each of the four crops where yield data had been collected, yields were higher for those irrigators who had a water meter. Whether this yield increase was an artifice of metering leading growers to better yields, or just to the fact that better managers simply owned meters is not known. The average relative yield increase was 6.9%. Since Missouri irrigators did not have any meters, relative yield differences were determined using the other three states.
- Irrigators were asked about how much of a reduction in pumping time was expected from a variety of irrigation water management practices. The question was a surrogate for how much water reduction may be expected from these practices. In the south, not all pumps have flow meters, so pumping time was used to estimate the expected water savings. One challenge was that over half the time (53.3%) survey respondents indicated no energy savings on the IBMPs they were rating. The IBMP having the most zero energy reduction scores was the adoption center pivot at 79%. Zero-grade had the lowest percent of all practices in tallying zero energy reduction scores (25%). Becoming efficient in using an IBMP may well be a learned trait. For example, on average, it was thought that using tail water recovery systems only reduced energy by 14%, but at the same time managing to have the survey's highest score on perceived energy reduction (90%). The mean values in Table 1 may reflect a skewing of results due to inexperience with the practice

in question that could improve over time. Therefore, the table also includes an average with the non-zeros removed that might represent possible savings for savvy practitioners once they had fully climbed the learning curve. Thus, for example, Multiple Inlet Rice Irrigation averaged a reduction of 13%, but when the non-zeros are removed, removing those that do not believe any savings exist, the reduction is 24%, more in line with published research.

- An underlying theme across the IBMP practices was that when farmers attempt IBMP practices on their farm and see the benefit this is the primary reason or motivation for adopting a new practice. Additionally, in the case of CHS and Surge irrigation learning about the practice at and Extension meeting was also a commonly expressed reason for adopting and implementing a practice. It is likely the two are more common, in that many farmers likely learn about new practices at Extension meeting and later try the practice on their farm as a demonstration working with their county Extension agent. In the case of MIRI especially, the reason for not adopting MIRI was that they tried it on their farm and it did not work. MIRI in particular can be a difficult practice to adopt at first, because how levees are blocked, pipe is installed, flows and gate setting are first implemented can be overwhelming for a farmer who has never tried it before. As such one on one assistance to help farmers and awareness and training by Extension with these practices have had a major impact in the region with the adoption of IBMPs.

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- Table 10. Irrigation: 2012 and 2007Table 24. Land Irrigated

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- Table 28. Land Irrigated in the Open by Method of Water Distribution: 2013 and 2008.
- Table 29. Land Irrigated in the Open by Sprinkler Systems: 2013 and 2008.
- Table 30. Land Irrigated in the Open by Drip, Trickle, or Low-Flow Micro Sprinklers: 2013 and 2008.
- Table 31. Land Irrigated in the Open with Gravity Irrigation by Field Water Delivery System: 2013 and 2008.
- Table 32. Estimated Quantity of Water Applied in the Open Using Only One Method of Distribution: 2013 and 2008.
- Table 33. Estimated Quantity of Water Applied in the Open Using Only Sprinkler Systems to Distribute Water: 2013 and 2008.
- Table 34. Estimated Quantity of Water Applied in the Open Using Only Gravity Flow Systems to Distribute Water: 2013 and 2008.
- Table 35. Crops Harvested in the Open from Irrigated Farms: 2013 and 2008.
- Table 36. Estimated Quantity of Water Applied and Primary Method of Distribution by Selected Crops Harvested in the Open: 2013 and 2008.
- Table 38. Selected Crops Irrigated and Harvested in the Open by Primary Method of Water Distribution – United States: 2013.
- Table 39. Water Management Practices Used by Operators with Gravity Systems for Acres in the Open: 2013 and 2008.

18 Appendices

18.1 Appendix I – Data Validity

Various responses given by the participant within the questionnaire are pertinent to his acre amount value calculated in ***Acres$_{CG}$***, ***Acres$_{IM}$***, and ***Acres$_{SF}$***. **Table 104** shows ancillary information from the dataset that may have bearing on the two outlier datapoints seen in **Figure 1**. The table includes total irrigated acreage amounts for datapoints **a** and **b** calibrated using three separate methods (***Acres$_{CG}$***, ***Acres$_{IM}$***, and ***Acres$_{SF}$***), the first two of which are on the x axis and y axis, respectively, in our figure. Survey ID, deviation off of the 1-to-1 line, and number of irrigation pumps are seen in columns [B], [C] and [H], respectively. Column [D] is the number of different crops that respondent was YES on, as well as, the number of these he reported some irrigated acreage for. The acreage per irrigation pump (relative to ***Acres$_{IM}$*** and ***Acres$_{SF}$***) is seen in column [I] and [J], respectively.

Table 103. Some of the survey data values associated with two different participants who exhibited outlier status.

Data Point	Survey ID #	Distance off from 1-to-1 Line	Irrigate Crop? YES / #	∑ Crop Acres	∑ Irrig Methods	∑ Land Surfaces	∑ Irrigation Pumps	Irrigated Acres per Pump		
[A]	[B]	[C]	[D]	[E]	[F]	[G]	[H]	[I]	[J]	[K]
a.	200,987	-11,400	3 / 3	11,656	10	4,000	100	0.1	40.0	116.6
b.	103,108	12,100	3 / 3	20,050	32,360	32,660	220	147.1	148.5	91.1

SOME POSSIBLE WAYS TO CROSSCHECK DATA

Datapoints, “á” and “b” are largely disparate from each other, causing them to be seen as being outliers. Ancillary information can possibly be used in providing useful analysis.

<u>Given</u>

Acres$_{CG}$* ≈ *Acres$_{IM}$* ≈ *Acres$_{SF}$

Each irrigation pump services about 150 acres.

Both participants said they grew 3 different crops; they also had supplied acre values for each.[1]

Regarding point a

- None of the three ∑ methods (***Acres$_{CG}$***, ***Acres$_{IM}$***, and ***Acres$_{SF}$***) agree → this is confusing???.
- The acres/pump: [I] = 0.1 is unreasonable; [J] = 40.0 is very low; whereas [K] = 116.6 is reasonable.
  - Conclusion: the ***Acres$_{IM}$*** value of 10 is way too low, and should be ≈ 12,000.

Regarding point b

- The values of ***Acres$_{IM}$*** ≈ ***Acres$_{SF}$*** thus validity is provided that the value of ***Acres$_{IM}$*** is correct.
- The acres/pump: [I] = 148.5 and [J] = 147.1 are reasonable; [K] = 91.1 is a bit low → ***Acres$_{IM}$*** value is too low.
  - Conclusion: the ***Acres$_{IM}$*** value of 20,050 it too low and should be ≈ 35,000.

[1]If answering YES to growing a crop, but late not listing any acres for it, then ***Acres$_{CG}$*** may be low. Note: 14.4% of respondents’ answers with YES did not include acreage

However, FYI, some avenues available for validating (and possibly correcting) pairs of datapoints are:

- Contrast datapoint value in all four of its summation methods (***$Acres_{CG}$***, ***$Acres_{IM}$***, ***$Acres_{SF}$***, and ***$Acres_{P}$***) – is there an odd man out?
- Had grower originally said YES he grew a crop, only to later indicating zero acres of it in 2015?
- Use the number of irrigation pumps owned to verify acreage (one pump serviced 100 to 180 acres).

Table 104 shows some of this ancillary data that might be used to validate one or the other of the two divergent datapoints "a" and "b" in **Figure 1**.

Table 104. Some of the survey data values associated with two different participants who exhibited outlier status.

Data Point	Survey ID #	Distance off from 1-to-1 Line	Irrigate Crop? YES / #	∑ Crop Acres	∑ Irrig Methods	∑ Land Surfaces	∑ Irrigation Pumps	Irrigated Acres per Pump		
[A]	[B]	[C]	[D]	[E]	[F]	[G]	[H]	[I]	[J]	[K]
a.	200,987	-11,400	3 / 3	11,656	10	4,000	100	0.1	40.0	116.6
b.	103,108	12,100	3 / 3	20,050	32,360	32,660	220	147.1	148.5	91.1

Should others wish to further investigate the notion of trying to modify some datapoint values in the *USBIS*'s database that appear as outliers, Appendix I contains information in this regard.

Note:

A less invasive way to "modify" the dataset is to just exclude flagrant outliers. In the case of Point "a", doing so increases R^2 from its value as shown as 0.7529 to a newer, higher level of 0.7927 (a gain of 4%). After dropping the point, *n* is still 99.8% of what it formerly was, and the sum and mean values of $\boldsymbol{Acres_{CG}}$ are 98.8% and 99.1%, respectively, of what they formerly were. Since the "a" datapoint's value for $\boldsymbol{Acres_{IM}}$ was so small (just 10 acres), other than the small percentage change in the value of n, nothing else changes noticeably.

18.2 Appendix II – Estimating Value of Datapoint with "I don't know" in the Dataset

However, in the cases where outlier datapoints resulted because one of the values in the pair had been reported as either being ZERO or just left blank (giving it a value of zero), substituting these ZERO-acre datapoints for ones "borrowed" from the unused dataset could be an option. Since **Figure 1** was comprised using the $\boldsymbol{Acres_{CG}}$ and $\boldsymbol{Acres_{IM}}$ datasets for the X- and the Y-axis, respectively, the unused dataset was the $\boldsymbol{Acres_{SF}}$ one.

Error! Reference source not found. is in three parts and shows [A] the same graph as the previous one, except ZERO-value datapoints included. The blowup [B] of the graphic showing some of the circled datapoints that are either ZERO or exceedingly low and will be exchanged. Plotting the corresponding $\boldsymbol{Acres_{SF}}$ values to these ZERO ones [C] against their corresponding crop acre values results in a very strong relationship (R2 = 0.864).

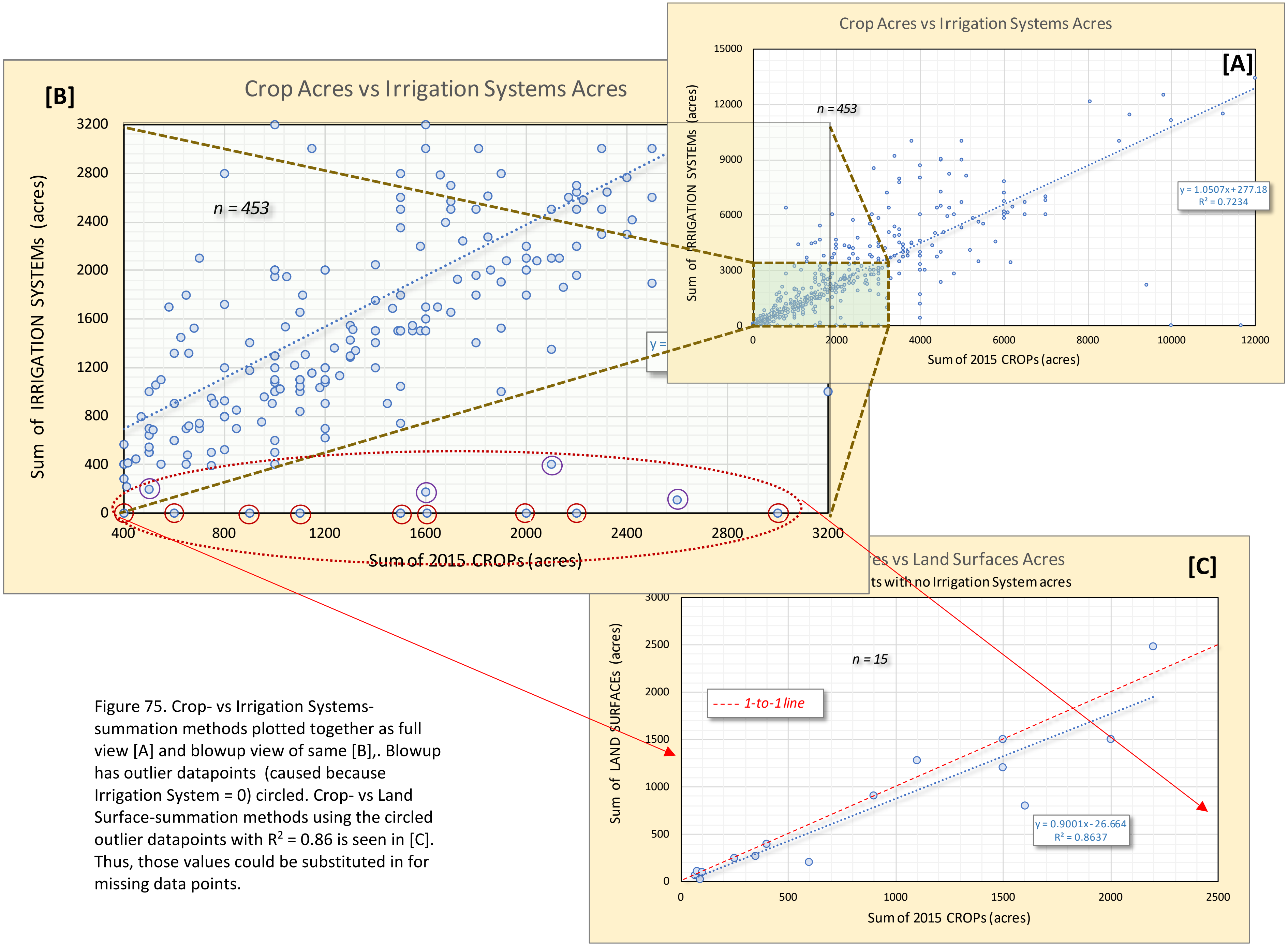

Figure 75. Crop- vs Irrigation Systems-summation methods plotted together as full view [A] and blowup view of same [B],. Blowup has outlier datapoints (caused because Irrigation System = 0) circled. Crop- vs Land Surface-summation methods using the circled outlier datapoints with R^2 = 0.86 is seen in [C]. Thus, those values could be substituted in for missing data points.

18.3 Appendix II – Dealing with Possible Errors in the Dataset

The data collected in the interview process reflected mid-South irrigation practices and their irrigated crops (along with their corresponding acreages) in place during 2015. The actual irrigated acreage for each respondent could be determined using several different approaches. The main two summing methods involved irrigated crop acres (*Crops Grown* [***CG***]) and the acreage serviced by the various types of irrigation systems (*Irrigation Method* [***IM***]).[24] However, some inconsistencies (i.e., errors) show up between the two main summing methods used, whereas in reality, the two methods should nearly be equal.

For both ***CG*** and ***IM*** inquiries, responses of I DON'T KNOW or REFUSED (although researchers purposefully included these as legitimate, understandable responses) would represent data points that were not available for use in calculating sums or mean values, and as such were left blank. If both the ***CG*** and ***IM*** lines of inquiry both received these type of response, then actual sum and mean were probably equally affected. However, should just one of the paired values have one of these noncommittal response then, while the difference between actual mean values may not be impacted very much, the differences between the sum values for ***CG*** and ***IM*** would likely be more effected.

Error, which carry over into totalizing amounts, could also be introduced when questions were not fully understood, as may have occurred with questions ***Q28a ... Q28c***, and since this question series belongs within the ***IM*** group, the error shows up on that side of the ledger. Also, in the process of a very long interview, the respondent in order to hasten the process, may have inferred a value of zero acres to the interviewer, rather than taking the time to mentally, or on a sheet of paper, make the required hand calculations to determine its actual value. Examples of possible data error:

- 14.4% of the time, after a grower had previously indicated he grew a crop under irrigation, would later report 0 acres of that crop
- Reporting more total irrigation pumps than total irrigated acres (which occurred ≈ 2% of the time).

However, other than the cases where some individuals' reported rice yields were suspiciously low, thought to be due to an apparent misunderstanding in the yield unit being asked for, over-riding of supplied answers was not done in this report.

It remained beyond the scope of this report to attempt modifying responses felt to possibly be inaccurate by using known relationships as a comparison; for example, when the number of reported irrigation wells on a farm and number of acres are out of synch with each other (generally each well supports ≈150 acres). However, several possible fact-checking, value-modifying procedures are found in Appendix I for others who may wish to examine this in further detail.

In summary, there may be small differences within our report for totalized irrigated acreage in the mid-South (and in the four involved states) depending on the tabulation parameters used in the calculation.

[24] Besides these two methodologies, supplied acreage data on soil surface finishing provided an additional back door that could be used in determining the number of irrigated acres of each participant.

18.4 Appendix III - Categories of Questions – Types of Information Garnished

There were over 150 opportunities in which a *USBIP* survey participant could provide information about himself and his irrigated farm by answering questions of varying forms. The answers from these questions could be used singly (e.g., average age of participant was 38 years), or combined with other responses to provide analysis (e.g., participants with some post high school agriculture education were more likely to use soil moisture sensors). The various sorts of questions and types of insight include:

- Practices used and the number of acres involved.
  - The % of farmers using the practice.
  - The survey's ∑of acres and ∑of users can be employed with Table 4 to project estimates for the whole mid-South.
- Background of participant.
- Impact visited on participants.
  - Energy savings

Much of the data collected in the *USBIS* was of a general, pooled nature. As an example, there were a series of questions regarding soil moisture sensors.

- The ***Q82*** Series :"*Which of the following methods do you use to schedule irrigation on your farm? [Check all that apply]*". ***Q82_9*** Soil moisture sensors. **√**
- Question ***Q84***: "On how many of your total irrigated acres are you using soil moisture sensors to schedule irrigation?" _100__ acres"
- The ***Q105*** Series: "… by what percent did pumping time decrease (if any) as a result of the change? ***Q105_10*** Irrigation scheduling methods such as … soil moisture sensors, etc.? _15__ %

So, if a farmer had two or three different crops watered by three or four different irrigation methods, there would be no way to identify that "it was this crop" or that "it was that irrigation method" which experienced those results. In short, crop-specific impacts are blended together.

18.5 Appendix IV -- Consistency in Survey Results

Early Study

In an earlier study (Edwards, 2016), the values of the summed crop acres compared to irrigation method acres did not closely coincide, with $\boldsymbol{Acres_{IM}}$ being about 50% greater for the whole region --and as much as 76% higher for one of the participating states, Arkansas. It appears that this issue may have been caused by a confusion on some of the components, possibly those involving furrow irrigation.

The $\boldsymbol{Acres_{CG}}$ levels – being based on just six crops-- might have underreported due to the missing irrigated crops. For example, wheat, melons, pumpkins, and sod are all crops that growers had specifically mentioned during the interview process, but for which no planted acreage information was ever collected. It is likely that the disparity between the two methods emanates from both sides.

While the confusion regarding interpreting the furrow irrigation questions has been resolved and brought the Ratio value to 1.18, that same confusion that first plagued the study interpreters, probably affected some of the farmers also.

As above, many acres of irrigated crops in the mid-South were not included in summing irrigated acres.

When summation methods are being totalized, if there is more use of prevaricated choices in answering (e.g., REFUSED, or I DON'T KNOW, or just leaving the question unanswered) in one summation method over another, that would affect the Ratio value.

18.6 Another Appendix

in the scope of this study to attempt making our calculations using "improved" data, future examiners might wish to do so (suggestions for doing so are provided in Appendix I). In the case that this effort would be undertaken, there then would be the potential for a fourth data set –one developed by future researchers using modified data:

- The number of on-farm irrigated acres compiled using modified data.

The main reason this augmented avenue is not pursued in our study is the authors feel that our data on user participation rate for various practices appears sound, and thus is the recommended metric for use in quantifying future changes among the mid-South irrigators. In 2015, for example, our own study showed that 27.4% of irrigated corn growers were using buried soil moisture meters somewhere on their holdings, and if in a future study it was found that 32.3% of corn growers were now using sensors then participation rate had increased by 4.9% points, an expansion of 17.9%. Actual acre amounts can then be estimated by multiplying these percentage values times amounts of irrigated corn from published government statistics.

18.7 Acreage count based on CORRECTED DATA

As hint at, some of the individual supplied responses are possibly incorrect, which in turn leads to the calculation of total irrigated acres also being inaccurate. Although not done in this report, there are three ways that could be used to "correct" suspected inaccurate data.

- Using hybridized data.
- Culling suspected "outlier" data.
- Using algorithms to adjust suspected data.

18.7.1 Deriving Acreage Based on Hybridizing Separate Data

The $\boldsymbol{Acres_{SF}}$ method appears to, ostensibly, be a good alternative estimate for calculating the irrigated acreage of participants (recalling its ratio to reported crop acres planted is 0.94 versus 1.50). However, this tactic itself still might be improved upon. This improvement is based on hybridizing the $\boldsymbol{Acres_{IM}}$ and $\boldsymbol{Acres_{SF}}$ datasets together by choosing between the two proffered, possible irrigation land values that one which is closest in the value to the partner $\boldsymbol{Acres_{CG}}$ value. This method is referred to as the hybridized method, $\boldsymbol{Acres_{HYB}}$, but again was not employed in our study results.

18.7.2 Deriving Acreage Based on Reducing Outliers

Lastly, if the two acreage values from a corresponding pair of $\boldsymbol{Acres_{CG}}$ and $\boldsymbol{Acres_{IM/SF/HYB}}$ of a producer greatly deviate from one another (and on not being sure which is "correct" and which is the "incorrect"), this pair could simply be culled before determining the mean and sum values. Culling a flagrant outlier, might appear to provide a more reliable mean, but it does result in reducing statistical procedures that can be used in evaluating differences between groups. Dropping a pair of values because they have divergent data points, eliminates the use of the Student t-test with dependent, paired values as a means of evaluating the mean between the two groups, since all values must have a corresponding partner.

18.7.1 Deriving Acreage Based Modifying Suspected Data

There were several ways within the database to double check responses. There were several cases of redundant questions within the survey, for example, a lead-off question asking for the total number of irrigation pumps, later followed with questions on the number of pumps for six different types of pump. Another, and very frequently used form of question redundancy, was to first ask if you used this practice, to be followed up later with a question on how many acres of that practice do you have. A YES response to the first question should result in a non-zero response for the follow up question. Inversely, a NO response at first should engender 0 on the follow up.

Algorithms could be employed to estimate. For example, it is possible to second guess indicated acreage amounts by using the respondent's reported number of pumps. **Figure 13** shows irrigated acres per pump for the mid-South. State by state values are given later in the report.

Again, supplied data values, even if they seemed questionable, were not changed. However, for those interested in the topic additional information could be found in Appendix I.

18.8 (5th) Overall RICE-Specific Acreage based on RICE CULTURAL PRACTICES

Rice, cultivated by 49.1% of survey growers, represented 20.2% of the *USBIP* acreage (**Table 76**). This crop was unique within the study in that it was the only crop for which its acreage component of $\boldsymbol{Acres_{IM}}$ could be totalized and, in part, validated by judiciously comparing results to summed totals of other rice-specific cultural practices asked about during the course of collecting irrigation data, such as in the questions of the ***Q47***, the ***Q103*****,** and the ***Q97*** series (see below).

Table 105 pertains to the reported 2015 RICE acreage when compared to the three datasets quantifying rice acreage (sum of rice irrigation methods, sum of rice watering methods, and prorated sum of reported land surface amounts). This last factor, the sum of reported land surface amounts for each rice farmer, is adjusted by prorating the farm's reported acreage amount (***Q47_1 … Q47_4***) as the percentage value of 2015 rice acres to the 2015 total crop acres. It can be seen that ratios of planted acres of rice to the three tallying methods are fairly much in agreement.

Interestingly, not only do three rice acreage methods have ratios similar to that reported to crop acres, but when Methods I to III are cross-referenced against one another (e.g., M_1 to M_2, M_1 to M_3, M_2 to M_3,) there is near unity. The fact that rice acreage constituted 20% of all irrigated crops and its data has been shown to be reliable, bodes well when all crops are analyzed. **Table 106** reports the participant size when all crops are studied and its subsequent size when only rice information is examined.

Table 105. Reported 2015 rice acreage value compared to rice acreage amount derived from reported irrigation method used, land surface amounts, and watering method amounts.

Rice Crop Acreage	Method I.	Method II.[A]	Method III.
2015 Planted Rice Acres	∑ Values from 5 rice irrigation methods	∑ Values from 4 Land surface acreages	∑ Values from 3 rice watering methods
Q137_4	∑ Q97_1 … Q97_5	∑ Q47_1 … Q47_4	∑ Q103_1 … Q103_3
207,368 acres	271,408 acres	195,092 acres	206,440 acres
(1.00)	(1.31)	(0.94)	(1.00)

[A] Total land surface amounts was multiplied by each farm's % of rice acres to total acres; collectively, this % was 20.25%.

Table 106. Methods to tabulate acres of rice

Type of Inquiry		Survey Statistics			
		All Crops		Rice	
		Number Responding	%	Number Responding	%
Farmers who responded		466	100.0%	229	49.1%
2015 Planted Acres		453	97.2%	204	89.1%
Method I	Irrigation Systems	445	95.5%	198	86.5%
Method II	Land Surface Forming	439	94.2%	---	---
Method III	Rice Watering Methods	---	---	193	84.3%

Table 76 shows the 2015 planted crop acres for all surveyed crops and for rice individually and the ratio of the two in all four states and the region as a whole.